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JPRS L/9301

15 September 1980

USSR Report

ENERGY

(FOUO 18/80)

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ELECTRIC POWER

UDC: 621.438.621.431.75

RESULTS OF THERMAL TESTING OF GTA-18 GAS TURBINE UNIT WITH RD-ZM-500 JET ENGINE

Moscow TEPLOENERGETIKA in Russian No 8, 1980 pp 23-28

[Article by Engineer V. G. Polivanov; candidates of technical sciences G. G. Ol'khovskiy, L. V. Povolotskiy, and M. P. Kaplan; engineers L. A. Chernomordik, A. O. Bumarskov, I. N. Skvirskiy, and P. I. Korzh; and Candidate of Technical Sciences A. G. Tumanovskiy, PO KhTZ-VTI Soyuztekhenergo]

[Text] Gas turbine units based on aircraft engines have come into widespread use in power engineering and industry abroad. Rolls-Royce (England) and United Technologies (Pratt and Whitney, United States), leading engine building companies, have set up special departments for development and production and have to date built thousands of such GTU [Gas Turbine Units], representing a total output of approximately 40 million kilowatts. Experience in ground operation has shown that utilization of advanced aviation technology and scientific-technical developments, the advantages of large-series production, as well as methods of development and securement of reliability of GTD [Gas Turbine Engines] adopted in aviation ensure high technical-economic and operational indices while retaining advantages connected with light weight and size of GTU and capability of very rapid (within 1.5-3 minutes) runup to full load. The power output of foreign GTU with a single aircraft engine currently reaches 30-35 MW, and their efficiency runs 32-34 percent.

In Soviet power engineering 1.6-3 MW units have found limited application, with various modifications of the AI-20 turboprop engine, as well as 4 and 12 MW units based on marine engines, designed the same as aircraft engines.

The GTA-18 unit, which is illustrated in Figure 1, is the first Soviet unit of fairly high (15-20 MW) power output with an aircraft turbojet engine.

The unit was designed and built by the Khar'kov Turbine Plant and installed at TETs No 3 of Khar'kovenergo for testing under commercial operating conditions. Following tuning and adjustment procedures and testing, the unit was able to operate normally with the designed parameters.

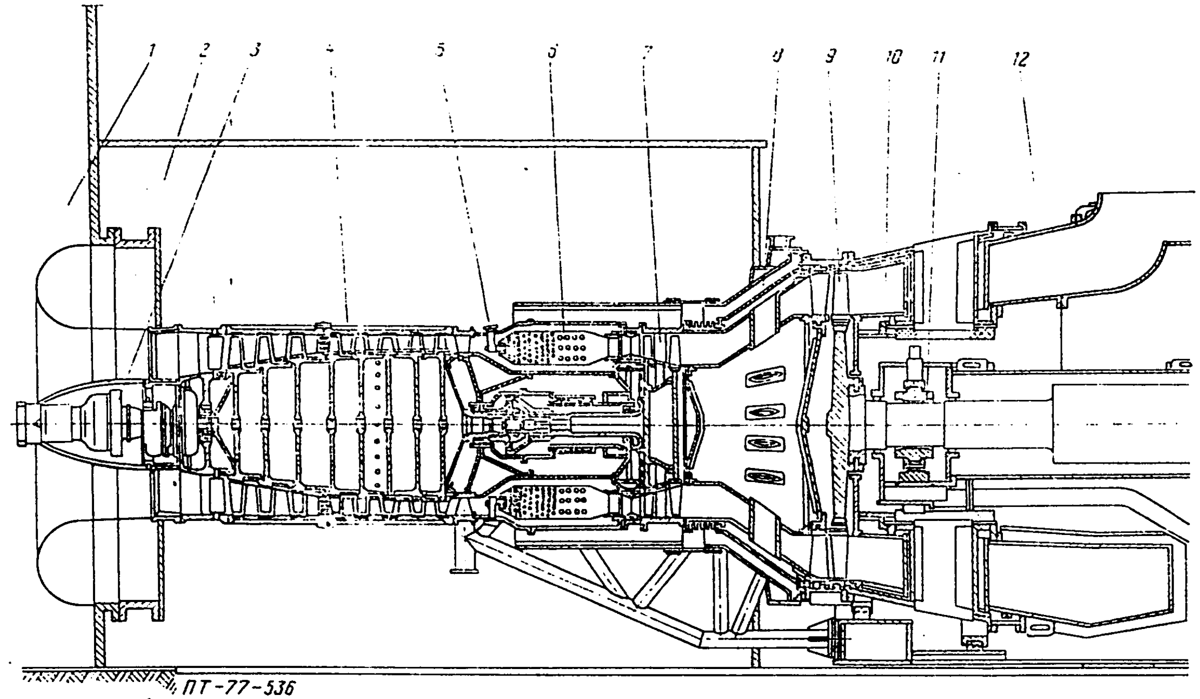

Figure 1. Diagram of Gas Turbine Unit (also see facing page)

Key:

1. Air intake chamber
2. Test cell for turbojet engine
3. Turbostarter
4. Compressor
5. Atomizers
6. Combustion chambers
7. Turbojet engine turbine
8. Connecting diffusor from turbojet engine to power turbine
9. Power turbine
10. Outlet diffusor
11. Power turbine bearing
12. Exhaust duct

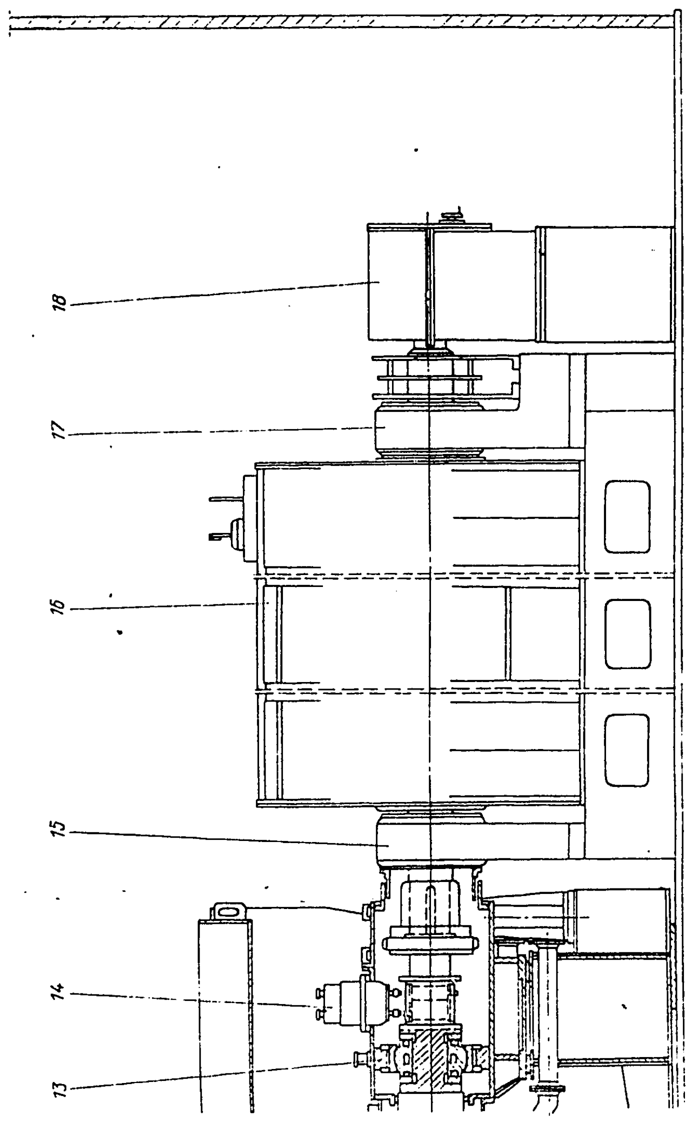

Figure 1. Diagram of Gas Turbine Unit (also see facing page)

Key:

13. Journal-thrust bearing
14. Automatic safety controls
15. Electric generator bearing
16. Electric generator
17. Electric generator bearing
18. Control unit

Preparation for thermal testing of the GTA-18 gas turbine unit did not specify a detailed study of individual aircraft engine components. Precise measurements of fuel consumption (with the aid of a precalibrated nozzle of quarter-circle section) and electrical load (with the aid of a precision class 0.2 three-phase wattmeter, plus an active power meter) were made to determine GTU economy. Gas temperature at TRD turbine exit (power turbine entry) was measured by eight regular thermocouples, positioned uniformly along the circumference in the inlet diffusor (three of these were subsequently replaced by four-point blocks), while gas temperature at the power turbine exit was measured with eight Chromel-copel thermocouples with open junction, mounted in the horizontal section of the gas duct from the GTU to the exhaust stack.

The main technical problem in engineering this unit was designing an economical power turbine and its linkup with the TRD, the level of gas velocities at the turbine exit of which is very high. As a consequence of this, in preparing for testing we paid special attention to setting up internal measurements in the blading.

Static pressures were taken from the walls to measure pressures at aircraft engine exit, power turbine entry, power turbine exit, and at the diffusor exit aft of the power turbine. Four holes were made in each section, at the root and periphery. Pressures were taken from each aperture by a pulse tube to external collectors, where the tubes were joined by manifolds (root and periphery in each section separately) and connected to differential pressure gauges filled with mercury or water. Static pressure at compressor inlet and exhaust duct exit was also taken from the walls through four apertures connected by annular manifolds. Two blocks with four pickups positioned at the centers of rings of equal area, on each block, were installed for direct measurement of total pressure aft of the power turbine at the diffusor inlet. These blocks were also used for taking samples of combustion products and determining chemical incomplete burning.

All GTU external indicators were calculated on the basis of measurement results. Cycle air consumption was determined from the heat balance in the GTU. Computations of total pressures and temperatures on the basis of measurement results were performed with the aid of gas-dynamic functions, and in the area aft of the TRD, also taking into account radial nonuniformity of velocities.

Thermal tests were performed with liquid fuel (jet-fuel kerosene and diesel fuel) at exterior temperatures of 20-27 and -2°C with loads to 19 MW, as well as with natural gas, with exterior temperatures of +5 and -10°C with loads to 18.5 MW.

The principal test results characterizing GTU indices are plotted in Figure 2 in relation to jet engine corrected rpm, and in Figure 3 -- in relation to GTU corrected power. The full temperature values presented in figures 2 and 3 were obtained from the power turbine power balance. The temperatures, measured at different points along the circumference of the blading aft of the jet engine differ from one another by 60-100 K (greater differences with lighter loads). The average measured temperature is 10 K higher than balance temperature, while maximum measured temperature is 50 K higher (Figure 4).

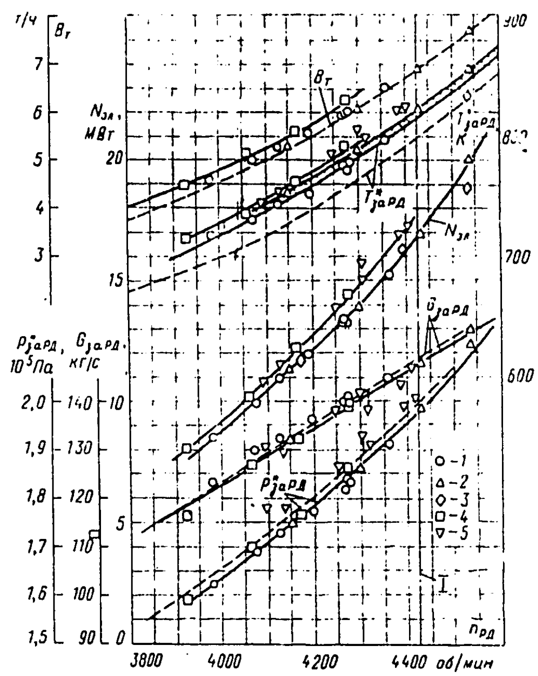

Figure 2. Relationship between parameters of GTA-18 and TRD rpm (corrected to ISA; $T_{нар}$ =288 K, B=1.013 x 10^5 Pa).

B_T -- fuel consumption; $T_{за\ РД}$ -- total temperature beyond TRD (calculated from power balance); $N_{эл}$ -- electrical load (exit); $G_{за\ РД}$ -- gas flow aft of TRD; $P_{за\ РД}$ -- total pressure aft of TRD; dashed lines indicate calculated values of parameters; I -- TRD rated operating conditions; 1 -- June 1977, liquid fuel, TRD No 1; 2 -- December 1977, same; 3 -- January 1978, natural gas, TRD No 1; 4 -- June 1978, liquid fuel; 5 -- October 1978, natural gas, TRD No 2.

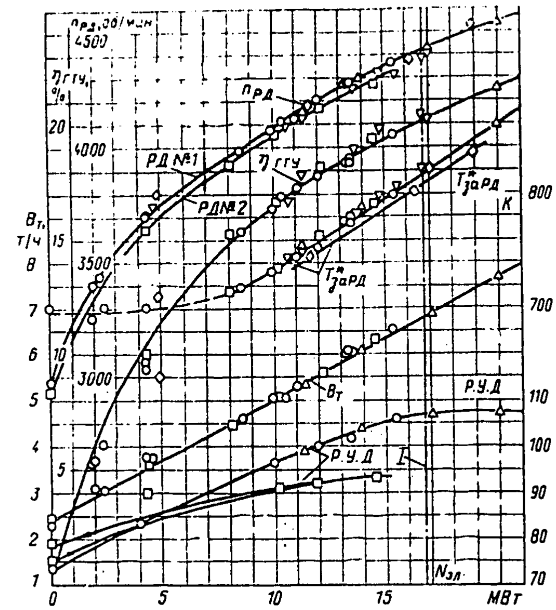

Figure 3. Dependences of GTA-18 parameters and indices on loads (corrected to ISA).

p.y.Д -- position of engine control lever; η TY -- GTU gross efficiency, heat flow; for other symbols, see Figure 2.

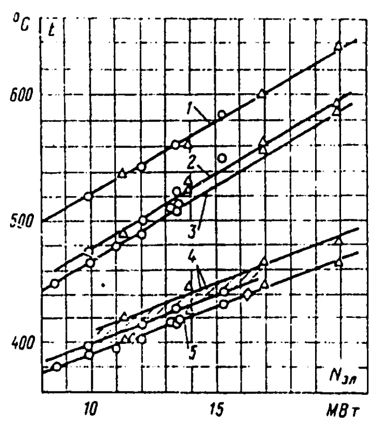

Figure 4. Characteristic gas temperatures operating on liquid fuel (corrected to ISA).

1 -- maximum temperature at TRD exit as measured by regular thermocouples;
2 -- average temperature at TRD exit, measured by regular thermocouples;

(Key to Figure 4 on preceding page, continued) 3 -- average temperature at TRD exit, calculated from power balance; 4 -- average temperature at power turbine exit, measured by regular thermocouples; 5 -- same, measured by laboratory-type thermocouples

It is evident from figures 2 and 3 that at rated corrected TRD rpm, GTU power and efficiency values in standard conditions are equal to 16.8 MW and 20.3 percent respectively.

Figure 5 shows the dependences of these indicators when $n_{ТРД} = n_{ном} = 4425$ rpm on ambient temperature and barometric pressure. It also contains data corresponding to delivery specifications. Tests indicated that GTU actual power and efficiency at the ambient temperature rated for the GTA-18 -- +5°C (278 K), are 18.6 MW and 21.1 percent. Power output is 1.9 MW (11 percent) greater than the guaranteed figure. All these indices are valid with the pressure losses obtained in the tests, which at operating conditions close to rated are equal to 0.2 kPa at entry and 1.5 kPa at exit.

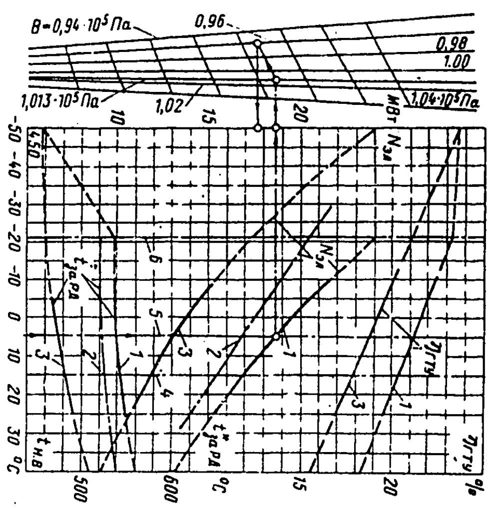

Figure 5. Dependence of GTA-18 indices on ambient conditions.

1, 2 -- rated ($n_{РД}$ =4425 rpm) conditions (1 -- actual, 2 -- calculated); 3 -- conditions 0.8 rated value; 4 -- ISA; 5 -- rate ambient air temperature; 6 -- maximum (rated) GTU power output conditions.

Example: $t_{нар}$ =+5°, B=0.96 x 10^5 Pa (720 mm Hg): from the diagram we determine $N_{эл}$ =18.6 MW on the base line with B=1.013 x 10^5 Pa and $n_{эл}$ = 17.6 MW when B=0.96 x 10^5 Pa.

At one stage in the process of testing the unit, the jet engine, serving as gas generator for the power turbine, was replaced by another, similar engine (No 2). The results of tests on the unit with TRD No 2 are also plotted in figures 2 and 3. As follows from the graphs, the GTU indices remained practically unchanged following replacement of the TRD, although the characteristics of the TRD proper were not entirely identical. One can assume, for example, that the turbine discharge capacity of TRD No 2 is somewhat (approximately 2 percent) greater, as a consequence of which, at the same TRD rpm, gas temperatures and fuel consumption proved to be somewhat higher, while air consumption was the same as in TRD No 1.

The GTU power output and efficiency values given above and in Figure 5 were obtained with TRD No 1. The unit with TRD No 2, at rated rpm, develops 0.6 MW more power with a correspondingly higher (5-10°C) exhaust gas temperature.

No increase in GTU power output on natural gas was discovered during the testing. The GTU efficiency values calculated on the basis of fuel consumption were lower, especially under partial loads, as a consequence of less complete combustion of the natural gas (see below); GTU efficiency values calculated on the basis of heat flow were practically identical.

The figures contained in Figure 3 also illustrate GTU characteristics under partial loads. It is evident from the figure that with standard ambient conditions heat flow on idle is 32 percent of the rated figure. GTU efficiency at half load is 15.1 percent; it is 24 percent (relative) lower than under rated operating conditions ($\eta_{50}=0.76\eta_{ном}$). At loads below 4 MW the engine operates with open bypass and dumping into the atmosphere (into the test cell) a considerable portion of the air compressed in the first compressor stages. Closing the bypass results in a power increase to 8-8.5 MW. As a consequence of increase in gas flow and pressure at engine exhaust which takes place with this, temperature at power turbine exit changes little. It begins to increase appreciably when $N_{эл}>8$-9 MW.

Since it was not possible because of design considerations to install full pressure strips downflow of the engine, in the area with the highest level of velocities (in tests up to 290 m/s), full pressure values in this area were calculated on the basis of average (between root and periphery) static pressure, temperature and velocity with corrections for the velocity curve (taken from figures for an analogous stage) and occurring flow spin. Both these corrections, following analysis, were adopted as constant for operating condition with load greater than 10 MW and equal in sum to 11.5 percent dynamic head, determined for average velocity with the aid of gas-dynamic functions. Conditionalities connected with this method of determining total pressure must be taken into account in evaluating test results. In particular, comparing calculated and experimental total pressure values and diffusor duct indices from engine to power turbine, one can assume that these conditionalities led to approximately 2 percent understatement of total pressure at engine exit (see Figure 2).

Degree of expansion in the power turbine ε^* at operating conditions close to rated figures comprises 1.75-1.85; available thermal gradient 125 kJ/kg, velocity of discharge 140-150 m/s ("losses" with velocity of discharge $Ac^2/2=11.3$ kJ/kg). Power turbine average efficiency values calculated on the basis of total pressures at TRD exit and exhaust duct exit are 84-85 percent, and 89 percent on the basis of total pressures at power turbine entry and at exhaust duct exit. These same efficiencies prove to be 2-3 percent lower when calculating on the basis of static pressure in the exhaust duct. Stage efficiency, calculated on the basis of total pressure at entry and exit from the blading, is 93 percent. This efficiency decreases by 1 percent with a load decrease from 15-20 to 8 MW and a u/c_0 increase from 0.5 to 0.7; efficiency decrease taking into account losses in the the exhaust duct, depending on operating conditions, is somewhat greater (2-3 percent).

Turbine discharge capacity with the rated ratio of expansion proved to be approximately 1 percent greater than calculated. With an increase in ratio of expansion to the rated figure and above, normalized turbine flow increases appreciably. Different dependences of turbine and nozzle discharge capacity on ratio of expansion may be one of the reasons for test results deviating from calculated engine throttle characteristics (Figure 2).

The characteristics of the duct from engine to power turbine (diffusor efficiency $\eta_Д$ and total pressure loss factor $\xi_Д$) are also practically independent of engine operating conditions.

Average values for efficiency and coefficient of total pressure losses in the duct, calculated on the basis of measured pressure at engine exit, are 84 and 17 percent.

Lower values ($\eta_Д=60\%$ and $\xi_Д=28\%$) are obtained with calculations based on total pressure taken from engine characteristic. Even they attest to the fact that the curvilinear duct from engine to power turbine, in which gas velocities decrease from 280-300 to 140-150 m/s proved aerodynamically sufficiently ideal.

Characteristics of the exhaust diffusor and the entire exhaust duct at operating conditions (with loads greater than 9 MW) are practically independent of u/c_0. Diffusor average efficiency is 55-60 percent, with 42 percent efficiency for diffusor with duct; average coefficients of total pressure losses in these sections comprise 29 and 41 percent respectively.

At operating conditions liquid fuel combustion completeness reaches 99 percent; on idle it comprises 97.5 percent. GTU exhaust at loads below 12-13 MW was entirely clean; at maximum loads it was slightly colored, but still remained clear. The degree of smoking, characterizing content of soot particles in the combustion products, was determined on the basis of darkening of filters through which a calibrated sample of gases was run (0 -- clean surface, 100 percent -- absolutely black filter surface). On idle it was 5 percent, and approximately 40 percent under a 20 MW load.

A concentration of soot particles corresponding to the latter figure is approximately 50 mg/m^3.

In tests with natural gas a decrease in completeness of combustion under light loads to 85 percent was observed.

Combustion chamber flame tubes in the RD-ZM-500 engine provides sequential entry of air into the flame zone. Highly-forced fuel combustion in chambers of this type is accompanied by the formation of comparatively small quantities of oxides of nitrogen. At GTU rated output their concentration in the exhaust gases is 0.0025-0.003 percent. With natural gas they are 0.005 percent less. Measurements of parameters were also taken during startup. GTU transition from reduced engine throttle to electric generator no-load running occurs with a moderate level of gas temperatures at power turbine entry and exit (not more than 450 and 400°C respectively). At reduced throttle static pressure at power turbine entry $p_{A\sigma CT}$ is 3 kPa (gauge), and thermal gradient Δi_s in the turbine is approximately 8.4 kJ/kg. Correspondingly at idle $p_{A\sigma\ CT}$=14-14.5 kPa (gauge), $\Delta i_s \approx 31$ kJ/kg. u/c_o values at these operating conditions are substantially (more than double) above rated figures.

A time study of start-up conditions indicated that engine transition to idle or reduced throttle takes from 80 to 120 seconds under different conditions. Maximum engine exit gas temperature values, recorded during this period with regular thermocouples, run 450-500°C. Power turbine start-up begins at 1300 engine rpm. If start-up is not forced after reaching reduced throttle rpm, power turbine run-up to rpm stabilization at 1500-1530 rpm requires 2 minutes. This time is somewhat greater with some start-ups. Performance of start-ups within the designed time frame (6 minutes to full load) encounters no technical difficulties. This time can also evidently be additionally reduced by 2-3 minutes.

Conclusions

With standard (ambient temperature +15°C) and rated ($t_{нар}$=+5°C) ambient conditions, GTA-18 power output runs 16.8 and 18.6 MW, with efficiency 20.3 and 21.3 percent respectively. The unit's power output is 1.9 MW (11 percent) greater than the design figure.

The increase in GTU power output and economy was a result of a certain increase in temperature at jet engine exit, but most important, a higher-than-calculated efficiency of the entire power turbine duct.

GTA-18 start-up occurs with a moderate level of temperatures at power turbine entry (not more than 450°C according to the readings of the regular thermocouples). Start-up and run-up to full load can be achieved in the design-specified time of 6 minutes.

The method utilized in the testing made it possible reliably to determine not only GTU external characteristics but also the internal characteristics of the power turbine duct.

3024
CSO: 8144/1651

ELECTRIC POWER

UDC: 662.6:621.311.22

INVESTIGATION OF IRSHA-BORODINO COAL SUPPLIED TO THERMAL ELECTRIC POWER STATIONS

Moscow TEPLOENERGETIKA in Russian No 8, 1980 pp 14-17

[Article by candidates of technical sciences G. G. Bruyer and M. Ya. Protsaylo, engineers A. A. Malyutina, G. S. Goreva, and V. S. Matviyenko, SibVTI: "Investigation of Irsha-Borodino Coal Supplied to Thermal Electric Power Stations"]

[Text] One of the long-range targets of thermal electric power engineering is extensive utilization of Kansk-Achinsk Basin coal -- our country's cheapest fuel. Facilities to be developed in the first phase of construction of the Kansk-Achinsk Fuel and Energy Complex (KATEK) include the Irsha-Borodino strip mine. This mine went into operation in 1950, with an annual coal production capacity of 1 million tons. At the present time this mine is being upgraded to a production capacity of 25 million tons per year. By the end of the Ninth Five-Year Plan the Irsha-Borodino mine, reaching 60 percent of planned output capacity, was the country's second largest strip-mine coal producer, exceeded only by the Bogatyr' mine in the Ekibastuz field [1].

Coal in the Irsha-Borodino field is humic, lignite. Its bulk weight ranges from 0.81 to 0.85 t/m^3, averaging 0.83 t/m^3, with ash content 10-12 percent. All coal technical composition indicators become worse in the following seam sequence: Borodinskiy I, Borodinskiy II, Rybinskiy. Moisture, ash and sulfur content increases. Content of volatiles and combustion heat decrease. The element composition also changes, with a decline in the content of combustible components. All this leads to a significant decrease in the combustion heat of the coal both for combustible mass and, especially, effective mass. The chemical composition of the ash is approximately the same in the Borodinskiy I and Rybinskiy seams, while Borodinskiy II is distinguished by an elevated content of acid oxides and decreased basic.

At the present time this coal field is the principal fuel base for several operating TES (Krasnoyarsk TETs-1, TETs-2, Krasnoyarsk GRES-2, Irkutsk TETs-6, etc). This fuel is also to be employed at new TES coming onstream -- Novokrasnoyarsk TETs-2, Ust'-Ilimsk TETs, Barnaul TETs-3, Novoirkutsk TETs, etc.

The following seams are presently being worked at the mine: Borodinskiy, Borodinskiy Yugovostochnyy, Borodinskiy II, Gusevskiy, and Rybinskiy. The production ratio is approximately as follows: 70 percent Borodinskiy, 22 percent Borodinskiy Yugovostochnyy, 7 percent Borodinskiy II, and Rybinskiy and Gusevskiy 0.5 percent each, of the mine's total production. Thus the principal coal quality indicators are determined by the Borodinskiy seam.

Commercial coal samples for analysis of seams at the Irsha-Borodino mine are taken by drilling holes on benches and pickets prior to mining, in conformity with GOST 11223-72. Average moisture content of the mined coal differs insignificantly from one picket to another and for the most part comprises 30.1-34.1 percent.

Average ash content, by seam, was as follows: Borodinskiy I -- 8.0 percent; Borodinskiy Yugo-Vostochnyy -- 10.7 percent; Borodinskiy II -- 14.7 percent; Gusevskiy I -- 13.0 percent; Gusevskiy II -- 9.5 percent; Rybinskiy -- 13.0 percent; Novyy -- 12.7 percent.

Coal production from seams with elevated ash content will have declined from 25 to 15 percent from 1975 to 1980. Overall average ash content at this mine is targeted at 9.0 percent by the end of the five-year plan.

The above-specified values of qualitative characteristics of seam samples of coal from the Irsha-Borodino mine determine quality of the coal as a whole but do not provide a picture of the significance of characteristics at the customer end, since they fail to take into consideration volume and dynamics of mining and shipping of coal from a given seam.

Statistical processing of quality analyses of coal from the Irsha-Borodino mine, performed at Krasnoyarsk TETs-1 and GRES-2, and at Irkutsk TETs-6, was done for the purpose of determining the quality of burned fuel at the customer end.

This study indicated that mining and delivery of coal are conducted in an extremely nonuniform manner. This occurs as a result of the uneven coal production from section to section and a lack of plan-specified distribution of fuel among customers. Fuel quality characteristics are for the most part in agreement between customer and supplier. Average monthly ash content ranges from 7.5 to 10.5 percent.

To study the chemical composition of the delivered fuel, SibVTI [Siberian Affiliate of the All-Union Institute of Heat Engineering] selected 84 representative samples from the seam at all benches at the strip mine, from railcars, and directly from the TETs conveyer belts.

Analysis of the fuel's combustible mass indicated that the element composition of Irsha-Borodino coal is practically constant and corresponds to average table values [2]. Yield of volatiles ranges between 44.6 and 47 percent of combustible mass.

The chemical composition of the mineral portion and its melting point showed sharp fluctuations for the different seams.

The mineral part of the Borodinskiy I seam has a chemical composition which is closest to the table figures. With an average ash content value A^c=8.0%, SiO_2 content comprised 40-45 percent and CaO 25-30 percent, with melting point t_3=1300-1350°C. With a decrease in ash content to 6.0-6.5 percent, CaO content increases to 35-40 percent, while SiO_2 decreases to 27-30 percent. t_3 increases thereby to 1450-1480°C. The lowest fuel mineral mass melting points are observed with an ash content of 8.5-10.0 percent and t_3=1250°C.

In some instances an increase in SiO_2 content to 70 percent with A^c=13% and $t_3>1500$°C is noted for the Yugo-Vostochnyy section, which is distinguished by elevated ash content.

The chemical composition of the mineral part of the fuel differs from tabular values to the greatest extent for coal from the Borodinskiy II and Gusevskiy seams. Here the mineral part is characterized as a rule by a high SiO_2 and low CaO content. With an increase in ash content to 20-25 percent, SiO_2 content increases to 70-80 percent, and the ash melting point is above 1500°C.

On the whole one observes for coal from the Irsha-Borodino strip mine a fairly clear-cut relationship between the chemical composition of the mineral mass and its fusibility characteristics on the one hand and ash content on the other. With an increase in ash content (Figure 1), there occurs an increase in SiO_2 content, while CaO content declines. In relation to ash content, melting point t_3 is of an extremal character, with a minimum at A^c=8.5-10%.

Mathematical processing of the results of analysis of coal samples collected by the institute from rail cars at power generating stations indicates that within an ash content range of 6-14 percent of dry mass, the relationship between CaO content in the ash and ash content of the coal is described by a first-order equation with a high correlation coefficient of 0.93:

$$CaO=57.2-3.15A^c,$$

where CaO is the calcium oxide content in the coal as a percentage of sulfateless mass; A^c -- ash content as a percentage of dry mass.

Contamination of the coal with silica occurs due to its impoverishment with associated rocks adjacent to the coal seam, for the most part sandstones and carbonaceous siltstones. As a consequence of the great thickness of the coal seams, this impoverishment does not exceed 0.5-1.5 percent. A more appreciable increase in the ash content of merchantable coal is observed with the presence of thin (500-200 mm) rock interbeds, which are practically impossible to remove separately from the coal with the existing mining process employed. This is typical of the Borodinskiy

II seam, which contains interbeds and lenses of sandstones with carbonaceous siltstones, which give the rock a carbonaceous color. The carbonaceous siltstone contains 70 percent ash, approximately 97 percent of which is SiO_2; its combustion heat for the effective mass comprises 1500 kcal/kg.

At the end of 1977 and beginning of 1978 experimental combustion of B2 seam Borodino coal was performed at Krasnoyarsk GRES-2. During the period of the tests ash content of the coal ranged from 5.2 to 25.2 percent of dry mass (see table). The chemical content of the ash changes with its increased percentage in the coal, as a result of introduction primarily of silicon oxide, increasing to 75-85 percent; the content of the remaining components decreases: Al_2O_3 fluctuates nonuniformly from 7.0 to 0.7 percent, Fe_2O_3 from 9.0 to 3.0 percent, CaO from 40.3 to 7.4 percent, MgO from 9.0 to 1.3 percent, SO_3 from 5.9 to 2.4 percent, and TiO_2 from 0.3 to 0.1 percent. One can trace a clear-cut relationship between coefficient of fusion and ash content of the coal:

$$K_{пл} = \frac{SiO_2 + Al_2O_3}{Fe_2O_3 + CaO + MgO},$$

where $K_{пл}$ -- ash coefficient of fusion; SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO -- percentage content of components of the respective oxides.

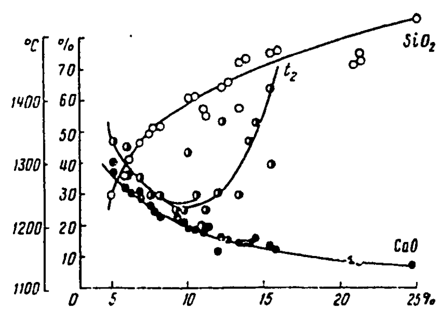

Figure 1. Relationship between SiO_2, CaO content in ash and its melting point t_2 on the one hand and ash content of the coal on the other.

This relationship can be expressed by the following first-order empirical formula:

$$K_{пл}=0{,}34A^c-1{,}2.$$

This formula applies to coal with an ash content from 5 to 25 percent.

As melting points decrease respectively, with an increase in ash content from 5.2 to 11.3 percent, from t_1=1280°C, t_2=1310°C, t_3=1330°C to t_1=1130°C, t_2=1170°C, t_3=1210°C, and then rise sharply with an increase in ash content by 1-2 percent, exceeding 1500°C.

(1) Зольность угля A^c, %	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SO_3	K_2O	Na_2O	$K_{пл}$	t_1	t_2	t_3
5,2	29,4	4,9	9,0	0,3	40,3	9,0	5,9	0,2	0,2	0,59	1280	1310	1330
6,1	36,1	6,8	7,7	0,3	33,6	7,3	6,6	0,1	0,2	0,88	1270	1300	1320
6,3	40,9	5,8	7,7	0,3	30,8	6,6	5,8	0,1	0,2	1,03	1240	1260	1280
7,1	45,5	4,5	6,5	0,2	30,5	5,3	4,7	0,1	0,2	0,21	1230	1250	1270
7,7	49,2	5,4	6,2	0,3	25,8	4,9	5,1	0,1	0,2	1,48	1180	1220	1240
8,4	52,1	6,3	5,7	0,3	23,6	4,7	5,0	0,3	0,2	1,72	1210	1240	1260
9,4	55,1	5,2	6,0	0,3	23,1	4,5	4,6	0,1	0,2	1,79	1180	1200	1220
10,2	61,3	3,6	5,5	0,2	20,0	3,5	3,6	0,3	0,5	2,24	1190	1280	1340
10,7	61,5	4,2	5,5	0,3	19,1	3,4	3,7	0,3	0,2	2,35	1160	1220	1280
11,3	57,2	7,0	7,2	0,4	19,3	3,4	4,3	0,3	0,3	2,15	1130	1170	1210
12,4	64,4	2,6	6,7	0,1	15,4	3,5	3,8	0,1	0,7	2,62	1250	1340	1370
13,6	72,4	2,1	5,2	0,1	14,0	2,8	3,1	0,1	0,2	3,38	1380	>1500	—
14,1	73,3	1,3	6,0	0,1	13,5	2,7	3,0	0,1	0,1	3,36	1450	>1500	—
15,6	75,4	2,3	4,7	0,1	13,0	1,6	2,9	0,1	0,2	4,02	1390	>1500	—
25,2	85,1	0,7	3,0	0,1	7,4	1,3	2,4	0,1	0,1	7,33	1460	>1500	—

Chemical composition of ash (%) and its melting point (°C) with various ash content of coal from the Borodinskiy II seam of the Irsha-Borodino field

Key:

1. Coal ash content

Most of the steam boilers designed for and operating on Irsha-Borodino coal are boilers with liquid slag removal, since they are more reliable as regards absence of slag formation on the heating surface with this coal. There have been cases of emergency shutdown of boilers with liquid slag removal in connection with extended supply of coal with refractory ash, caused by ash clogging the slag hole. In connection with this, a study was made of the operational reliability of boilers fired by Irsha-Borodino coal.

Maximum combustion gas temperature in the combustion core for furnaces with liquid ash removal (without special measures to boost temperature in the firebox, heating air to 600-700°C, for example) does not exceed 1600-1650°C. For normal slag escape gas temperature in the melting area should exceed t_3 by 100-150°C, that is, the mineral part of a fuel with $t_3 < 1480$-1500°C will melt and normally escape in such fireboxes.

Slag from Irsha-Borodino coal with an ash content of less than 12.5 percent (Figure 1) has such a melting point. But as a rule the melting point of the boiler slag is 100-150°C higher than the melting point of the mineral part of the original coal, due to redistribution of acid and basic components of the mineral mass between slag and ash. The upper limit of coal ash content ensuring normal liquid slag removal can be approximately pegged at 11.5-12.0 percent.

At the Irsha-Borodino mine 12-15 percent of the coal produced has an ash content above critical. Overall coal ash content does not exceed 9.0 percent, that is, the average annual coal quality indicator for the mine as a whole does not present a hazard for combustion in furnaces with liquid slag removal. Combustion of three to four hours even of high-ash coal does not produce an emergency situation. In order to avoid emergency boiler shutdowns it is essential to know the quality of the supplied coal prior to its delivery to the power generating station, to keep precise records of it and to store coal with a specified ash content at separate specified locations in the storage area.

In case of continuous burning of high-ash coal for a period of three-four hours when there is the danger of clogging the slag hole, one can utilize the method of reducing the slag melting point by fluxing it. This method, extensively utilized in metallurgy, has not become very widespread in fuel combustion, but for fuels with an ash content of 20-30 percent it is not expedient to employ this method, since a large quantity of fluxing material is required. Another complex problem is that of uniform distribution of fluxing material in the fuel being burned. This causes a power generating plant additional expense not only for the flux itself but also for its preparation during fuel handling and pulverizing. Feeding flux with the pulverized coal leads to reduction of combustion figures. Finely ground flux is for the most part carried out of the furnace in the form of ash, with an insignificant portion actually utilized, settling in the slag.

SibVTI, working jointly with Krasnoyarsk TETs-1, proposed and tested a method of fluxing with coarsely dispersed material (1-10 mm), which was fed through firebox access holes directly onto the combustion bed. This made it possible to reduce sharply flux consumption.

Minerals with high calcite content can be employed as flux for slag with a high silica content.

To estimate the quantity of calcium oxide additive, laboratory tests were performed with the addition of 5-40 percent CaO to a slag sample taken at Krasnoyarsk TETs-1, with its melting point determined (Figure 2). The relationship between the melting point of the mineral part and the addition of CaO enables one to conclude that the addition of 5-7 percent calcium oxide to slag reduces its melting point to a level ensuring good slag discharge.

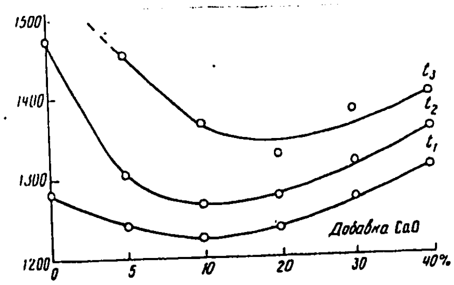

Figure 2. Relationship between slag melting point and addition of CaO (composition of initial slag: $SiO_2=63.8\%$, $Al_2O_3=4.9\%$, $CaO=16.4\%$, $MgO=2.8\%$, $Fe_2O_3=8.0\%$, $K_2O=0.25\%$, $Na_2O=0.25\%$).

Due to the relatively low ash content even of the high-ash Irsha-Borodino coal, CaO consumption is negligible. For a BKZ-320 boiler, for example, coal consumption runs 60 t/h, while slag yield runs 3.6 t/h. Flux consumption will be only 200 kg/h. Annual flux requirements per boiler will apparently not exceed 60 tons, and therefore boilers with liquid slag removal should be equipped with permanent units for fluxing.

Good effect is produced by combined combustion of Irsha-Borodino high-ash coal with Berezovskiy low-ash coal, the ash of which contains up to 50-60 percent CaO.

We should note that when Irsha-Borodino coal is burned in fireboxes with liquid slag removal, in some instances so-called "melting" slag is discharged from the slag hole. Upon discharge, such slag does not sink in the water of the slag bath and, accumulating on the surface, forms slags which are difficult to remove. This slag consists 85-90 percent of glass, possesses higher porosity and lower thermal conductivity than normal slag, in which glass comprises only 45-50 percent. Fluxing with lime can be employed to combat "melting" slag.

Conclusions

1. Statistical processing of materials on the quality of coal from the Irsha-Borodino strip mine indicated that qualitative characteristics are similar from the figures of supplier and customer. Average annual coal ash content for the period studied comprises A^c=9.1-9.2%, while the ash content of merchantable samples ranged from 6.5 to 25.5 percent.

2. A chemical analysis of the coal ash indicated that a relationship between the chemical composition of the mineral part and its fusibility characteristics on the one hand and ash content on the other is observed. With an increase in ash content there is an increase in SiO_2 content and a decrease in CaO. The ash melting point is at a minimum when A^c=8-10%.

3. Mining and delivery to power generating plants of coal from the Borodinskiy II seam, with an elevated ash content (approximately 15 percent), is not harmful to fireboxes with liquid slag removal under the condition that average daily ash content does not vary by more than 1-2 percent from the average annual value. If this condition is not met, it is necessary to employ slag fluxing or combustion together with coal with an elevated content of basic oxides.

BIBLIOGRAPHY

1. Vitkovskiy, K. V. "The Kansk-Achinsk Coal Basin -- This Country's Fuel and Energy Base," in the volume "Gorizonty KATEK" [Horizons of KATEK], Krasnoyarsk, 1977, pp 20-44.

2. Matveyeva, I. I. "Energeticheskoye toplivo. Spravochnik khimika-energetika" [Boiler Fuel. Handbook for the Chemist-Power Engineer], Moscow, Energiya, 1972, Vol 3, 215 pages.

3024
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COAL SLURRY PIPELINE

Moscow STROITEL'STVO TRUBOPROVODOV in Russian No 5, 1980 p 22

[Unattributed article: "Pipeline for Hydraulic Transport of Coal"]

[Text] Construction and movement on-stream of the Belovo-Novosibirsk experimental-commercial coal slurry pipeline is scheduled in these next few years.

The general client and general designer of the pipeline is the USSR Ministry of Coal Industry, which has been assigned the designing and construction of facilities to prepare coal for transport in the form of a coal-water slurry, as well as operation of these facilities and the pipeline proper.

The Ministry of Construction of Petroleum and Gas Industry Enterprises is providing design and construction of the pipeline proper and pumping stations. The Soyuztransprogress Association has been given the job of manufacturing nonstandard equipment and building at the test facility at Ramenskoye a test bench for testing full-scale pumps and hydraulic fittings for mainline coal slurry transport systems.

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PIPELINE CAPSULE TRANSPORT OF VISCOUS OIL AND PETROLEUM PRODUCTS

Moscow STROITEL'STVO TRUBOPROVODOV in Russian No 5, 1980 pp 26-29

[Article by D. B. Ibragimov, V. A. Meliya, and F. A. Karimov of VNIIPI-transprogress; Yu. A. Bokserman and S. M. Vaysman, Kiev Affiliate of VNIIST: "Pipeline Container Transport of Viscous Crudes and Refined Products"]

[Text] The oilfields of Western Siberia contain for the most part valuable high-viscosity crudes, production of which is steadily increasing. One basic difficulty involved in exploiting these reserves is the transport of such crudes under difficult climatic conditions, with permafrost and sharp seasonal temperature fluctuations.

The method of transmitting crude oil in a heated state, employed in the southern regions of this country, such as in the Uzen'-Kuybyshev pipeline, cannot be employed under these conditions, for a number of reasons which are specific to "hot" pipelines. High temperature differentials occur when heating crude, which require effective means and methods of insulation, which have not been sufficiently developed up to the present time. Under permafrost conditions there occur with "hot" transmission of crude ecological problems connected with subsoil thawing and irreversible changes in the subsoil temperature balance. More than 10 percent of the transported crude, which is a valuable chemical feedstock, is burned at heating stations sited along the route.

The elevated temperature of crude transport significantly accelerates the rate of pipe corrosion, which causes intensive wear and even rupture. In contrast to conventional crude oil pipelines, any halt to the pumping through of high-viscosity crudes results in rapid congealing of crude in the pipeline and puts the line out of operation for an extended period of time.

In addition to preheating, there are also other methods of preparing viscous crude for pipeline transmission: heat treatment, dilution with low-viscosity liquids or gases, aqueous solutions of surface-active substances, etc. These methods have not been extensively employed, for technical, process and, principally, economic reasons.

At the present time industry needs not only proposals for improving known methods of pipeline transport of viscous crudes but also fundamentally new technical solutions.

A team of scientists and experts from VNIIPItransprogress [expansion unknown] proposed a pipeline-capsule method of transporting such products. Development of a system applicable to the conditions of the Tyumen' Oil and Gas Region is in progress, working jointly with Giprotyumenneftegaz, the Siberian Scientific Research Institute of the Petroleum Industry, and the Kiev Affiliate of the All-Union Scientific Research Institute for Construction of Trunk Pipelines.

The potential utilization of trunk pipeline continuous-capsule systems (MTPKS) is dictated by their reliability, high capacity, and economy.

A comparative analysis of technical-economic substantiations (TEO) of a number of proposed systems for transporting high-viscosity crudes from the Russkoye oilfield revealed the advantages of MTPKS.

With utilization of MTPKS, a stream of interconnected capsules moves at a constant velocity within a transport pipeline, along the entire length of the line. This stream of capsules is powered by stationary propulsion devices (for example, electromagnetic) built into the pipeline at specified intervals and working in coordination with the capsule propulsion components. To ensure guaranteed tension and for performing preventive maintenance without shutting down the system, there is a gap on the pipeline, within which individual units are separated from the continuous hookup and removed to a preventive maintenance station (RPS), with repaired units simultaneously reinserted into the line. Figure 1 contains a schematic diagram of the MTPKS.

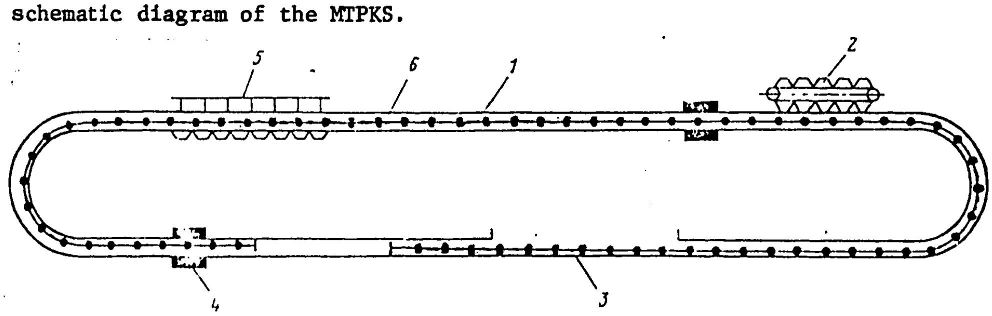

Figure 1. Schematic Diagram of Pipeline Continuous-Capsule System

In addition to transporting crude oil and refined products, an MTPKS can transport by the return leg liquid, bulk and construction materials needed in the oilfield area.

Charging and discharging are basic MTPKS subsystems, which provide continuous feeding of transported materials.

For the transport of high-viscosity crudes and refined products, it is necessary to develop totally new charging-discharging units, which ensure requisite system capacity. Let us first examine the mechanism of solidification of crude oil in capsules. We shall employ an approximate model of this process developed by Academician L. S. Leybenzon.

Region $b \leq r \leq R$ will be in a solid state, and region $0 \leq r \leq b$ will be in a liquid state. Here R is the radius of the cylinder (capsule); b -- traveling radius of phase boundary. We shall introduce the following symbols: T_0 -- initial temperature of the crude oil; $T_{\text{пов}}$ -- temperature on the capsule surface; $T_{\text{гр}}$ -- temperature at the phase boundary (in this instance -- crude oil solidification point; $T_{\text{гр}}=T_{\text{з}}$).

It is assumed that $T_{\text{пов}} \leq T_{\text{гр}} \leq T_0$.

A thermal conductivity equation can be written for the region $b \leq r \leq R$:

$$\frac{\partial^2 u_1}{\partial r^2} + \frac{1}{2} \frac{\partial u_1}{\partial r} = \frac{1}{a_1} \frac{\partial u}{\partial t} \qquad (1)$$

with boundary conditions $u_1=T_{\text{пов}}$ with $r=R$, $u_1=T_{\text{гр}}$ with $r=b$, (2)

where t -- time; r -- current radius of cylinder; $u_1(r, t)$ -- temperature of solid phase; a_1 -- coefficient of solid phase thermal conductivity.

For the region $0 \leq r \leq b$ it is assumed that initial temperature T_0 is equal to solidification point $T_{\text{гр}}$ and is constant throughout the entire volume

$$u_2=T_0=T_{\text{гр}}=\text{const}, \qquad (3)$$

where $u_2(r, t)$ -- temperature of liquid phase.

At the boundary of solidification (when r=b), there occurs the condition of Stefan's phase conjugation

$$K\rho_{\text{ж}} \frac{db}{dt} = \lambda_{\text{тв}} \frac{\partial u_1}{\partial r} - \lambda_{\text{ж}} \frac{\partial u_2}{\partial r}, \qquad (4)$$

where K -- crude oil latent heat of fusion; $\rho_{\text{ж}}$ -- density of the liquid phase; λ, λ_{TB} -- coefficients of thermal conductivity of the liquid and solid phases respectively.

The initial condition for equation (4) will be

$$b/_{t=0}=R \qquad (5)$$

In the assumption of steady-state temperature conditions (that is, $\partial u/\partial t=0$), we obtained a cylinder solidification curve

$$t = \frac{K\rho_{\text{ж}}R^2}{2\lambda_{\text{тв}}(T_{\text{гр}} - T_{\text{пов}})}\left\{\frac{1}{2}\left[1 - \left(\frac{b}{R}\right)^2\right] - \left(\frac{b}{R}\right)^2 \ln\frac{R}{b}\right\}. \quad (6)$$

We shall obtain complete solidification time (b=0) as a particular case of equation (6)

$$t_{\max} = \frac{K\rho_{\text{ж}}R^2}{4\lambda_{\text{тв}}(T_{\text{гр}} - T_{\text{пов}})}. \quad (7)$$

As an example we shall perform calculations with formula (6) for plotting solidification curves for crude oil in a 315 mm capsule (350 mm diameter pipeline), at various ambient temperatures (Figure 2).

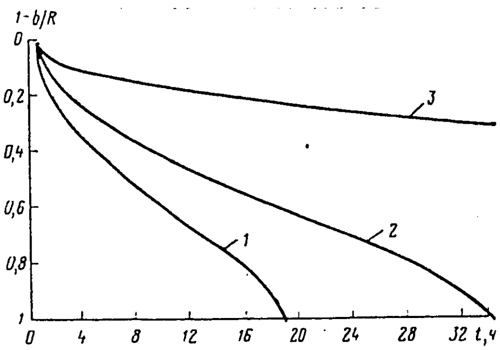

Figure 2. Relationship Between Degree of Solidification of Crude Oil and Time: 1 -- 10°C; 2 -- 20°C; 3 -- 30°C

In our calculations we employed the physical properties of viscous crude oil from the Uzenskoye field: $T_{\text{гр}}$ =+32°C; K=11 kcal/kg; λ_{TB}=0.138 kcal/m·h·°C; $\rho_{\text{ж}}$=833 kg/m^3.

The curves show that with limited transport time and sufficiently high $T_{\text{пов}}$, only the outer layer of crude oil solidifies.

According to condition (3) of the adopted model, at the initial moment the entire original volume has a solidification point of $T_{\text{гр}}$=32°C. In practice crude oil is poured into the capsule at a higher temperature -- T_0=50-70°C. The period of time during which the crude oil cools from temperature T_0 to $T_{\text{гр}}$ "postpones" initiation of solidification and thus decreases the oil solidification layer.

Curves were plotted (Figure 3) to estimate cooling time from T_0 to $T_{\text{гр}}$ with the same input data on the basis of calculations of convection in a confined space taking into account gradual change in physical properties of crude oil with a decrease in temperature. The coefficient of heat transfer from the capsule surface to the surrounding medium was determined on the basis of known ratios for convection during pipe longitudinal flow.

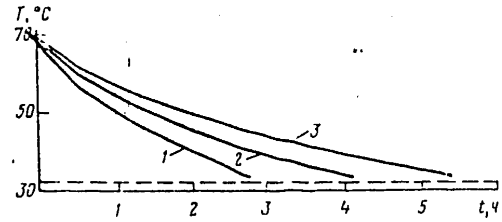

Figure 3. Relationship Between Crude Oil Cooling Temperature and Time: 1-3 -- same as in Figure 2

Thus with specified initial and terminal conditions and known geometric capsule dimensions, one can determine from the graphs in Figure 2 the degree of crude oil solidification (thickness of outer layer) during transport.

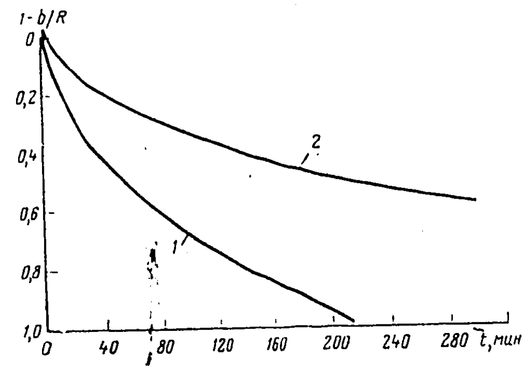

Figure 4. Relationship Between Degree of Crude Oil Liquefaction and Time: 1 -- 300°C; 2 -- 100°C (T_0=20°C)

Let us examine the possibilities of calculating liquefaction of a specified volume of crude oil with capsule immersion in a medium with specified temperature $T_{пов}$. In this instance

$$T_0 \leqslant T_{гр} \leqslant T_{плав} \leqslant T_{пов}.$$

In spite of change in the direction of heat flow, the type of phase conjugation equation (4) remains the same.

For the region $0 \leq r \leq b$ thermal conductivity equation (1) can be written with boundary conditions $u_1(r, t)=t_{гр}$ with r=b

$$\frac{\partial u_1}{\partial r} = 0 \quad \text{with } r=0, \tag{8}$$

and initial condition $u_1(r, t)=T_0$ with t=0. (9)

Problem (1), (8), (9) can be solved with the employment of a Laplace time transform.

In view of the laboriousness of the proposed calculations, we shall take as a first approximation

$$\left.\frac{\partial u_1}{\partial r}\right|_{r=b}=\frac{T_{\text{гр}}-T_0}{b}. \qquad (10)$$

For the region $b\leqslant r\leqslant R$

$$\left.\frac{\partial u_2}{\partial r}\right|_{r=b}=\frac{T_{\text{пов}}-T_{\text{гр}}}{R-b}. \qquad (11)$$

Integration of equation (4) taking into account expressions (10) and (11), with initial condition (5), gives the following cylinder liquation curve equation:

$$t=\frac{K\rho_{\text{тв}}R^2}{A+B}\left\{\frac{B}{A+B}\left[1-\frac{b}{R}+\frac{A}{A+B}\ln\frac{B}{(A+B)\frac{b}{R}-A}-\frac{1}{2}\left[1-\left(\frac{b}{R}\right)^2\right]\right]\right\}, \qquad (12)$$

where

$$A=\lambda_{\text{тв}}(T_{\text{гр}}-T_0),$$
$$B=\lambda_{\text{ж}}(T_{\text{пов}}-T_{\text{гр}}).$$

In a particular case, cylinder complete liquefaction time (when b=0) will have the form

$$t=\frac{K\rho_{\text{тв}}R^2}{A+B}\left\{\frac{B}{A+B}\left[1+\frac{A}{A+B}\ln\left|\frac{B}{A}\right|\right]\right\}. \qquad (13)$$

The graphs in Figure 4 have been plotted as a result of calculations with formula (13).

An analysis of the graphs shows that complete liquefaction time, even with a heating medium temperature $T_{\text{пов}}$ =300°C is too great and, consequently, if during transport time the entire volume of crude oil in the capsule solidifies, heating from the surface is ineffective as a means of ensuring pouring. It is necessary either to seek qualitatively different modes of emptying containers, such as scouring with streams of heated crude oil, driving out with compressed oil or gas, change in capsule design, or one must obtain the possibility of substantially increasing heating time.

As indicated earlier, however, under certain conditions only the surface layer of crude in the capsule solidifies. In this case heating from the surface may prove sufficiently effective and economical.

The proposed method was utilized in elaboration of technical-economic substantiation of a continuous-capsule system designed for transporting viscous crudes from the Russkoye oilfield a distance of 150 km.

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CONSTRUCTION OF 750 KILOVOLT POWER LINES

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 7, Jul 80 pp 46-49

[Article by Engineer K. A. Pogrebkov: "Experience in Construction and Directing Development of 750 Kilovolt Overhead Lines"]

[Text] From the editors. A rapid increase in power generating capacity and efficient transmission of electric power to consumers are correctly considered to be determining conditions for successful accomplishment of economic tasks as a whole. A decisive role in this regard is played by modern power transmission lines of 750 kV and up. Our country's electric power engineers have amassed considerable experience in construction of such lines.

We offer this journal's readers another selection of materials on construction of 750 kV power transmission lines, a selection prepared with the participation of builders and designers.

For more than 10 years now USSR Minenergo [Ministry of Power and Electrification] has been carrying out an extensive program of construction of 750 kV power transmission lines. Much work has been accomplished during this time: a total of 2,600 km of such lines has been erected, as well as nine powerful transformer substations with a total installed capacity of 16.5 million kVA, during construction of which builders, designers and operators had to solve highly complex problems. These 750 kV overhead power lines were erected under various, at times extremely difficult geological and climatic conditions. Power line routes ran across swampy terrain, forest tracts and high mountains, crossed such major rivers as the Volga, Dnieper, etc, as well as thousands of major electrified rail lines, highways, high-voltage power lines, communication lines, crude oil and natural gas pipelines, etc.

Within a comparatively short period of time our country has amassed enormous experience in building such high-voltage overhead power lines. Thanks to employment of new and advanced structural designs, adoption of advanced job organization methods, and implementation of a number of other measures, these facilities meet today's high demands.

CPSU Central Committee General Secretary Comrade Leonid Il'ich Brezhnev, Chairman of the Presidium of the USSR Supreme Soviet, noted in his message of greeting to the work forces of construction, installation, operation, engineering design organizations, machine building enterprises, and all entities participating in construction of the Vinnitsa (USSR)-Albertirsa (Hungarian People's Republic) power transmission line that this line, which has no equal in Europe, was constructed swiftly and with excellent quality of construction and installation work.

USSR Minenergo has drawn up and coordinated with USSR Gosplan a plan of further development of 750 kV overhead power transmission lines for the coming five-year plans. Implementation of this program will ensure maximum efficient utilization of the electric power generated by dozens of mighty power stations under construction in the European part of the USSR.

The November (1979) CPSU Central Committee Plenum stressed the necessity of building high-voltage main power transmission lines. Already under discussion is future construction of 1,150 and 1,500 kV AC and DC overhead power transmission lines.

Thus we can already analyze 10 years of experience in building 750 kV overhead power lines and substations, elucidate unresolved problems, and specify ways to achieve further improvement in construction of high-voltage power transmission lines.

As experience of extended operation has shown, the design organizations of the Energoset'proyekt Institute have designed reliable, economical and aesthetically-pleasing 750 kV power transmission lines and substations. Such 750 kV substations as the Donbass, Vinnitsa, Western Ukrainian, and Belyy Rast have deservedly received high praise from the client organizations. They are reliable in operation and are distinguished by high quality of performance.

The cost of building power transmission lines has dropped significantly. For example, the cost of construction and installation work on the Vinnitsa-Dnieper 750 kV overhead power line, built in 1971, was 55,000 rubles per kilometer, while the figure was 42,000 rubles for the Kursk-Bryansk overhead power line, built in 1979.

The materials requirements of the structural designs have decreased. In 1971 an average of 17 tons of rolled metal was consumed per intermediate portal-type tower, while the figure was down to 12 tons in 1979. Following design improvement, weight of the Nabla intermediate support decreased by 8 percent, and with its employment on overhead lines running across forested terrain, the required cleared right-of-way width was reduced by 12 meters.

At the same time we cannot agree with the claim that design institutes, when designing 750 kV overhead lines, proceed not from maximum line transmission capacity but seek to reduce line cost also by the device of employing conductors of the smallest possible diameter. As a result the cost of an overhead line of course is reduced in some measure, but the power line's transmission capacity also drops, which is extremely undesirable. In the author's opinion, lines of this voltage category should be designed on the basis of achieving maximum transmission capacity.

Nor are builders happy about the fact that design institutes have designed eight types of intermediate supports in the last 10 years for 750 kV overhead lines, for each new type of support must go through a period of fabrication startup. As a rule it is necessary to set up new fabrication lines and equipment for these structures. Design engineers should bear in mind all these important factors prior to making any significant changes, and they should comprehensively economically substantiate an adopted design solution.

There is no excuse for lengthy delays in preparation of engineering drawings of new structures. The intermediate support tower for the Kursk-Bryansk 750 kV overhead power transmission line was designed with a year's delay, for example, and the plants of the Energostal'konstruktsiya Trust received the drawings (at the KMD [expansion unknown] stage) 5 months before the line was scheduled to go into service.

At the present time builders are employing intermediate supports of two types -- the portal type, and the Nabla support. The portal-type tower requires less labor to erect than the Nabla, requires a minimum quantity of equipment, is more convenient for erecting bare conductors, and occupies less right-of-way space. This tower should be employed on routes crossing cropland. But in inaccessible, marshy and forested areas employment of the Nabla support is warranted, since fewer supports are required per kilometer of line.

The people at Glavtsentrelektroset'stroy have on numerous occasions made suggestions on improving the design of substations. Without going into the question of employment of SF_6 equipment in this article, the adoption of which depends chiefly on USSR Minelektrotekhprom [Ministry of Electrical Equipment Industry], we feel that it is expedient to discuss the necessity of utilizing in substation construction rigid leads, sharply reducing buried lines and auxiliary facilities. Implementation of these measures alone will substantially reduce the cost of construction and erection work, cut metal consumption almost in half, and substantially reduce substation (SS) construction site area.

Unfortunately designers still tolerate the manufacture of obsolete and sometimes entirely useless structures by the plants of Glavelektrostroyprom and continue to employ them in the design of high-voltage substations. We must immediately cease utilization in construction of 750 kV substations of type USO rack frames, cable trays, brick for erection of walls and partitions, with elaboration of measures to reduce labor-intensive jobs, particularly plastering and painting, etc. We should work more resolutely for the adoption of inexpensive high-quality advanced structures and materials, which will make it possible not only to reduce the cost of building substations but also improve their exterior and interior appearance.

The SS construction site must be transformed into an erection-installation site, with prefabricated units and assemblies installed in the construction of large SS. We have all the prerequiistes for this. It is necessary only to unify the efforts of designers, builders and officials at industrial enterprises of USSR Minenergo.

In the opinion of the experts at Glavtsentrelektroset'stroy, adoption of new, advanced structures and replacement of obsolete structures in power distribution system construction should occur not less frequently than once every five years. We should particularly emphasize that their adoption in production should be preceded by preliminary testing at test facilities, involving the participation of leading experts from design, construction, industrial and operating organizations. It is essential that these tests not become mere lip-service formalities but that test results find practical application. The construction people at Belyy Rast, for example, built test sections of an 1150 kV AC overhead power line and a 1500 kV DC line, and also made comments on the adopted design solutions. In designing similar commercial-designation lines, however, the designers, instead of adopting appropriate corrections, replaced the prior-tested types of supports with new designs and supported the client's demands that test sections be built on the main line. The builders in turn, who must meet the state plan targets, are compelled to obtain manufacture and delivery of several thousand tons of as yet untested structures of a new type. Obviously there are no guarantees that these structural designs will prove acceptable. Other complaints are also made against the designers. As we know, metal structures are computed for strength in laboratory conditions. As has happened more than once, however, support tower crossarms have deformed when the bare conductors were erected.

There should be mandatory testing of supports under field conditions. Overhead power line sections of 2-2.5 kilometers in length should be built, for both construction and operation tests, determining all the pros and cons, and only after this making the final decision on adoption of new structural designs in power distribution construction. The cost of such test facilities is small, while economic benefit is great.

In examining the problem of improving efficiency in construction of power transmission lines of 750 kV and up, one must also consider the role of the client. Elimination of the Main Administration of Capital Construction at USSR Minenergo, which at one time performed the functions of client in construction of 330-500 kV power transmission lines, led to considerably greater complexity both in designing and building ultrahigh power lines. Delayed issuing of technical documentation and delays in gaining official transfer of right-of-way land and work permits, initiation of financing, etc, have become chronic, which on the whole delays construction of power transmission lines and frequently leads to a situation where the generating capacity of newly on-stream power stations is "locked off," as it were.

What kind of construction by plan and schedule is it when the client (UDP [expansion]) did not issue authorization to the builders until the end of 1979 to commence work on the Smolensk Nuclear Power Station-Bryansk 750 kV overhead power line? It is obviously high time once again to return to the question of establishing in USSR Minenergo an organization performing the functions of a single client for power distribution network construction facilities.

Whether or not power distribution system facilities come on-stream on schedule depends to a significant degree on the quality of preparatory work. The time spent by the builders on studying the power line route, establishment of job superintendent base facilities, supply receiving facilities, study of vehicle approaches to right-of-way construction points and construction of temporary access roads, establishment of worker housing sites, etc is justified. Experience has shown that the better the quality of preliminary engineering, the faster the pace of construction will be, the better the quality of the work, and the lower the cost. It is essential that power line right-of-ways be transferred over in advance, approximately one year before commencement of preliminary work. We believe that USSR Minenergo should submit such a suggestion to the superior organization.

The problem of environmental protection is becoming increasingly important with each passing year. The Presidium of the USSR Supreme Soviet and Soviet Government have passed a number of appropriate laws and decrees. USSR Minenergo regularly reminds power distribution system facilities builders of the necessity of reducing losses of agricultural land, of taking measures to prevent soil erosion, and to ensure the preservation of planted greenery. At the same time questions pertaining to environmental protection are many times not fully reflected in the construction standards and regulations which guide clients and design organizations. This is partly the reason for the following, for example. In designing the Pechora-Usa 220 kV overhead power transmission line, which runs through marshy-forest terrain far from inhabited localities, the client and designers failed to consider the fact that the route cuts through bird nesting areas. As a result considerable detriment was done to the native fauna. In their flying back and forth, birds would hit the wires and be killed. Unfortunately there are a number of such examples. Designers run many power transmission line routes parallel to highways. This disrupts the landscape. Application of obsolete standards leads to unwarranted width of cleared right-of-ways for overhead power transmission lines.

There are many unresolved matters. It is evidently time to establish in USSR Minenergo a special Regulation on Design, Construction and Operation of Power Distribution System Facilities, which would make it possible substantially to broaden and supplement existing construction standards and relations in effect in this area and to guarantee protection of the environment.

Matters of supply have been, are and continue to be principal items in elaborating measures pertaining to improving construction activities, increasing labor productivity and reducing construction cost. Calculations show that with well-organized, smoothly-running logistical support in construction of power distribution system facilities, labor productivity can be boosted by 25-30 percent. In recent years much has been done in the administrations of USSR Minenergo both to improve supply of overhead power lines and substations under construction and to improve the quality of supplied metal structures, insulators and line accessories. Glavsnab calculates requirements in rolled metal products on the basis of descriptive documents (they have been adopted in recent years). The Domodedovo, Konakovo, Donetsk and other plants have improved quality and set completeness on supplied metal towers. At the same time the supply system of power distribution network facilities under construction requires further improvement. For example, it is necessary to revise, and as soon as possible, present standards pertaining to stocks of structures and materials on hand on power transmission lines and at substations under construction. According to present standards, these stocks are established on the basis of 24-28 days work. Experience in power distribution system construction indicates that the minimum quantity of structures on hand should be figured for 110-120 days. These stocks on hand should be considerably larger in the Far North and Arctic. Then there will be less idle time at construction sites, an improved equipment and vehicle utilization factor and, what is also important, construction of power transmission lines will cause minimal damage to farmlands (in the winter, when the ground freezes and planted acreage is covered with snow).

Construction of overhead power lines of 750 kV and up extending 250-300 kilometers should not begin until construction site supply areas contain 75-80 percent of the requisite quantity of structures, conductor, insulators, and line accessories. If just this condition is observed, utilization of the available equipment and vehicle fleet will almost double. Many years of experience in high-speed production-line construction of 750 kV overhead power transmission lines confirms this.

As is evident from the above, resolution of many problems depends on higher-level organizations. GPTUS [expansion unknown], for example, should have long ago listened to the opinion expressed by builders and clients and drawn up a regulation on full supply and supply schedules for line accessories and insulators and on liability of supplier plants for failure to deliver supplies for which they are at fault. At the present time the functions of main supplier of line accessories are performed by the Soyuzelektroset'izolyatsiya All-Union Production Association. And it would seem that supply of the association's product items to construction jobs is in direct relation to the efforts of association staff. In 1979, for example, delivery of all line accessories and insulators for 35-110 kV power distribution network facilities in the Belorussian SSR was scheduled for the fourth quarter, regardless of when the facilities were scheduled to come on-stream, and nothing could be done to correct this patently abnormal state of affairs.

In the author's opinion, construction organizations should order line accessories and insulators, refine delivery timetables, and issue necessary supply documents. Clients should not merely handle payment for delivered insulators and line accessories.

It is essential precisely to coordinate the delivery timetables on line accessories, insulators, conductor, cable, and make Glavenergokomplekt organizations responsible for issuing appropriate work orders. The manufacturing plants should perform the functions of executors of work orders issued by this main administration.

Coordination of matters pertaining to delivery of conductor, line accessories, towers and other structures leaves much to be desired. We could cite a great many examples of conductor being delivered to a construction site, but no line accessories, or delivery of supports but no cable for erecting them, etc. It is even worse when supports are delivered but no foundations have been prepared, etc.

Analyzing the balance sheet of a construction organization, one frequently sees that carryovers of materials are substantial, and yet it is practically impossible to work, because those materials and structures which are needed at the moment are not those which were delivered. Do the GPTUS people know about this? Yes, they do. But they do not bear responsibility for completing facilities and putting them on-line. This is probably the reason for such an attitude.

We should state that the principal power distribution system organizations also do not always objectively appraise requirements in structures and materials. Orders are at times overstated, and the ordering process is done poorly.

Power distribution facilities builders accomplish each year an enormous volume of work for the USSR Minenergo as a whole. Successful completion of construction depends on skilled solving of problems at all levels of management. This is especially important in those cases where decisions made by high-level administrators reflect on the subsequent performance of many other organizations.

The journal ENERGETICHESKOYE STROITEL'STVO has on numerous occasions discussed experience in construction of 750 kV overhead power transmission lines. These articles have examined a broad range of questions pertaining to preliminary work, establishment of intermediate assembly facilities, organization of job superintendent sections with housing and production facilities, organization of worker meal service, adoption of means of small-scale mechanization, selection and placement of cadres, work involving the brigade contract method, that is, all that which as a whole makes it possible to cut facility construction time at least in half. In view of the fact that in the 11th Five-Year Plan the bulk of work volume increase should be achieved by boosting labor productivity, it is necessary, alongside new measures to achieve intensification of production, to devote adequate attention to structures and methods of job organization which have proven effective in the past. In construction of power distribution system facilities, for example, it is necessary to renew mass employment of pile, poured and bored pile foundations. Extensive adoption of reusable take-down formwork, provision of such equipment as vibration pile driving units, cranes for erecting 26 meter reinforced concrete supports, as well as support carriers, truck concrete mixers, small concrete plants, and further specialization of subdivisions will make it possible in many parts of this country to eliminate costly, high metal-consumption prefabricated reinforced concrete structures.

There is also much other reserve potential for boosting labor productivity. For example, in 1979 Glavtsentrelektroset'stroy, during construction of the Chernobyl'skaya Nuclear Power Station-Rovno 750 kV overhead power transmission line (the route passed through marshy-forested terrain), organized an exchange of experience and know-how in erecting metal intermediate towers. It was determined that with proper organization of labor a combined brigade can erect during a work shift not one but from two to three towers. This requires setting up combined teams of 28-30 power line erection workers, equipping them with several sets of rigging, erection booms, hinge links, etc. Labor productivity on such teams can realistically be approximately doubled without increasing the quantity of equipment.

But the fact is that at the present time the main administration has available less than half of the requisite number of T-100 tractors. Actually a trust performing an annual work volume of 30-35 million rubles and more is authorized a maximum of 60 tractors of this type. If we consider that each trust has an average of six mechanized columns, one can easily calculate how many pieces of such equipment each receives.

At one time the main administration was forced to specialize 12 mechanized columns exclusively on construction of 220-750 kV power transmission lines, and 10 mechanized columns on construction of 220-750 kV substations. As a rule these mechanized columns are not employed to erect 35-110 kV lines (the main administration has 24 combined mechanized columns to perform these jobs). Such specialization has in the past helped successfully bring on-stream not only 220-750 kV power transmission lines but also has helped perform a large volume of work on lower-tension overhead power transmission lines.

Today, however, the power line construction people are faced with more complex tasks, which are impossible to accomplish without a suitable fleet of modern vehicles and equipment.

Erection of uninsulated conductor and lightning protection cables has become one of the bottlenecks in power line construction. Construction conditions on power transmission lines are frequently such that existing equipment cannot be employed. In particular, frequently it happens that the T-100 tractor is not powerful enough to reel out conductor. There are no vehicles for reeling out conductor under tension. There are no cranes with good off-road capability for erecting metal towers. Power line construction gangs are not equipped with 200-ton pressing units, there is a shortage of small-scale mechanization equipment, various devices, etc. These problems can be solved only if the ministry has a large industrial enterprise specializing in the manufacture of equipment for power transmission line construction. It is essential that the journal ENERGETICHESKOYE STROITEL'STVO carry an extensive discussion and debate on problems of mechanization of the entire aggregate of construction and erection work involved in putting up power transmission lines.

It is impossible to examine simultaneously all matters connected with increasing the effectiveness of power distribution system construction in light of the new tasks. Particularly meriting attention are such problems as development of new models of line accessories and insulators which meet world standards, improvement in the quality of reinforced concrete structures, as well as problems of planning, economics, etc.

The journal ENERGETICHESKOYE STROITEL'STVO (No 1, 1980) contains an article by Comrade P. P. Falaleyev, First Deputy Minister of Power and Electrification USSR, entitled "Improving Efficiency of Power Industry Construction -- A Component Part of Improving the Mechanism of Economic Management." In the author's view, one of the principal tasks is that of securing a balance between plans and financial, material and labor resources. Problems pertaining to power industry construction, specified in the report by Comrade Leonid Il'ich Brezhnev at the November (1979) CPSU Central Committee Plenum, should be resolved precisely on such a foundation.

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FIRST 750 KV POWER TRANSMISSION LINE IN MOUNTAIN TERRAIN

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 7, Jul 80 pp 49-53

[Article by Engineers O. P. Tikhanova, Ye. N. Kalinin, and Ye. A. Kruglikov: "Construction of First 750 kV Overhead Line in Mountain Conditions"]

[Text] Following construction of the first full-scale 750 kV electric power transmission line, the Donbass-West, it became possible to connect up the big USSR Southern Power Grid to the CEMA member nations (the Mir Electric Power System). The Vinnitsa-Western Ukraine substation (USSR)-Albertirsa (Hungarian People's Republic) 750 kV power transmission line became this connecting link. A section of this line, the first mountain-terrain overhead transmission line of its kind in Europe and in the USSR, runs for 125 kilometers across the Carpathian Mountains, a region of complex geology and weather.

In spite of the relatively low elevations in the Carpathians along the power line route (elevations to 1,000 meters) and the gentle slopes on the right-of-way, considerable difficulties arose during design and construction of the power line due to the large size and weight of the structures involved.

Basic Design Solutions

The mountain section of the line is categorized as a region IV for icing, and at elevations above 800 meters -- a special region with maximum dynamic wind pressure of 0.76 kN/m^2 (wind velocity 35 m/s).

As we know, engineering design of overhead power transmission lines is determined principally by diameter of conductors and phase layout. Phase variants with 4AS400/93, 5AS300/66, and 6AS240/56 were considered for this power transmission line. Since the variants being compared differed from one another by only 3-5 percent in calculated outlays, preference was given to the phase with four AS400/93 conductors, which is an approved arrangement and makes it possible significantly to increase span length, which is extremely important in mountainous terrain. In cross section the phase is a square 60 cm on the side, at the corners of which the conductors are positioned.

Employment of steel-cored aluminum lightning protection cables made it possible to use them for high-frequency communication channels, automatic line fault relays and protection. AS95/141 cable was employed across the mountains, while AS70/72 cable, developed and adopted on this power transmission line, employed on flatland stretches, was unsuited for long spans in mountain areas ice-rated IV and special.

The presence of mountain slopes, the limited size of sites suitable for erecting large towers, and elevated wind and ice loads (especially on stretches where the route crossed mountain passes) -- all these factors dictated the necessity of developing a series of special supports of various configuration.

At the preliminary design stage five intermediate support designs were developed for the mountain section (Figure 1). Following analysis of the final study materials, however, only two principal intermediate support designs were adopted: portal type anchored by guy wires (PMO-32, Figure 1a), for erection along route segments with moderate slopes and in foothills, and double-support, on separate towers (PRS, Figure 1b), for erection on steep slopes.

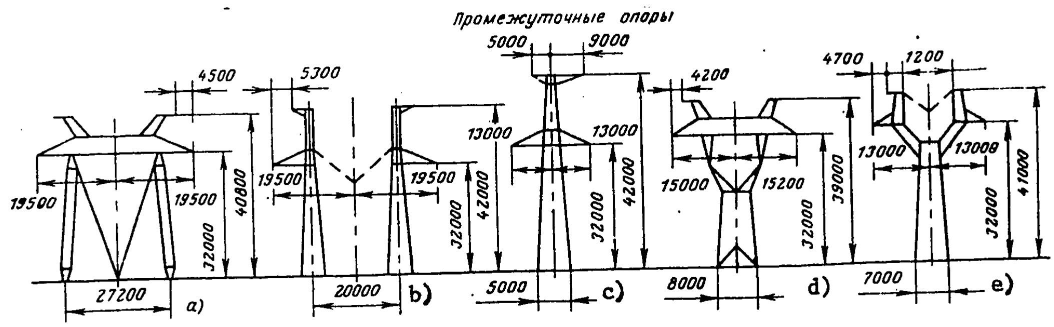

Figure 1. Diagrams of Intermediate Supports.

a -- portal type, anchored by guy wires; b -- double support, on separate towers; c -- single tee-arm support; d, e -- "wine glass" type, single support, with horizontal and triangular positioning of phases respectively.

When erected on slopes, the PMO-32 portal-type tower has one shortened support: support height can be reduced by 1.6-4.8 meters, depending on steepness of slope. The tower weighs 13.5 tons.

The PRS support with separate towers was employed not only on steep slopes but also wherever topography required higher towers. PRS support towers are erected independently of one another, at different levels. The middle phase conductors are suspended from a V-shaped supporting insulator string. Depending on the elevation difference between tower bases, the point of attachment of the insulator string branches moves along the tower cable strut, and with large elevation differences the height of one of the cable hanger arms is increased by adding a support (Figure 2). The base of each tower measures 3 x 5 m. The PRS support weighs 19.1 tons.

Reinforced supports of both types (PMO-32u and PRSu) were employed on stretches with elevated wind or weight loads. All towers are of the bolted type, of galvanized low-alloy steel.

Angle supports comprise three separate towers. Two phases are run past the towers with the aid of a flexible loop with the insulator string drawn to the neighboring tower, and the third phase -- with the aid of an inflexible horizontal loop (Figure 3) [figures 2 and 3 omitted]. In the special-rated icing area a flexible loop was employed for the third phase, with the loop drawn to an additional fourth tower.

The design of the angle support with separate towers for a 750 kV line proved especially appropriate for mountain conditions since, displacing each of the towers in a lateral or longitudinal direction to the axis of the power transmission line, as required, one can select the most suitable sites for the towers and can also employ towers of differing height.

We should note that when erecting towers with displacement of position, it becomes impossible to draw the flexible loop toward the neighboring tower. In these instances the advanced GSh-750-11 inflexible horizontal loop design is extremely convenient for running each phase loop around its tower. Such a loop is more convenient than a flexible loop, since careful adjustment is not required during installation. An inflexible loop makes it possible fully to utilize the advantage of separate siting of angle support towers, which is practical and expedient not only on mountain terrain but also in constrained site conditions (for example, in power line corridors, at intersections with other overhead power transmission lines, on power generating plant industrial site flexible couplings, etc). In addition, in contrast to a flexible loop, this arrangement does not require an additional tower, which makes it possible to reduce the size of the site occupied by the support. Employment of these loops has been adopted by the installation crews of the Yuzhelektroset'stroy and Yuzhzapelektroset'stroy trusts.

Delivery of inflexible loops was sometimes delayed during construction of the power transmission line. In order not to disrupt the normal pace of construction, in these cases flexible cross loops were employed. They can be used, however, only on towers at least 25 meters tall, at line turn angles up to 35° and where the support towers are not mutually displaced.

Determination of positioning of supports along the route profile across the mountain section was performed in three stages. Initially preliminary support positioning was determined in the office, determining tower location sites, which must be field-inspected. The support centers were then marked out on the overhead transmission line route, with inspection of sites at which tower erection would be difficult for any reasons. The purpose of these inspections was to determine conditions of vehicle access as well as to determine the possibility of laying out the support towers during assembly and placement of equipment during tower erection. When necessary new tower locations were determined, and those route segments were identified where partial route change or long spans would be necessary. This job was performed by the power line production design engineers, a surveyor and a representative of the mountain area contractor mechanized column. All recommendations made by this team were worked up in the third, final stage of tower siting.

Considerable attention during planning and designing the overhead power transmission line was devoted to the matter of tower foundations, a job involving considerable difficulties. The ground supporting tower foundations along the mountain section of the line consisted of highly-weathered and partially unweathered andesite-basalts. Due to an abundance of springs and creeks, many tower sites were subject to flooding and landslides. In addition, land in the Carpathians is assigned to the category of valuable land, disturbance of the integrity of which leads to an irreversible process of slope collapse, occurrence of landslides, disturbance of natural groundwater drainage, etc. Taking all these factors into consideration, the engineers designed special foundations: bored pile foundations with piles 630 mm in diameter and from 3 to 12 meters in length. The foundations were to be constructed by drilling a foundation borehole with cable tool drilling rigs, erected a reinforcing cage with secured anchor bolts, and filling the borehole up with poured concrete. The problem of erecting towers on hillside sites was successfully solved by the capability of varying the height of the above-grade portion of the foundation.

Construction of such foundations would result in minimal disturbance of the natural slopes, and volume of work involved in foundation reinforcement and water diversion would be insignificant.

To determine the supporting capacity of bored pile foundations, two sites were selected, with geologic conditions typical for the transmission line route, and appropriate field tests were performed. It was necessary to abandon the idea of bored pile foundations, however, because the construction organizations were inadequately equipped with cable tool drilling rigs, mobile concrete batching units, etc, and the builders lacked experience in doing work of this type.

The towers were secured in the ground with the aid of precast reinforced concrete plugs and slabs. Foundation excavation was performed by excavators and bulldozers, while bedrock was blasted with explosives. As a result of employment of precast reinforced concrete foundations, at many tower erection sites it was necessary to perform special reinforcement work and to construct upslope ditches and gutters to divert runoff.

Deep tubular steel pile foundations were designed and built for erecting towers sited on river floodplains with meandering watercourses and considerable predicted depth of general and local washout erosion. These foundations were built under each tower foot, as follows. Single steel pipes 720 mm in diameter would be sunk to a depth of from 17 to 25 meters. Then a reinforcing cage would be positioned, and the pipe filled with concrete. These foundations provide reliable tower foundation support with ground eroded out to a depth of 6-8 meters. Construction of these foundations was contracted out to a specialized organization.

At the initiative of the Energoset'proyekt Institute, an attempt was made to employ bedrock foundations for securing towers. Tests were performed. There was very little integral bedrock along the route, however. In most places one finds heavily-weathered rock close to the surface. To reach solid bedrock suited for rock foundations, it was necessary to remove overlying weathered rock to a depth of 1.5-2 meters, a sufficient depth for placing conventional reinforced concrete foundations. Therefore bedrock foundations were not employed on this route.

Cable-cable melting of ice is provided on 750 kV overhead power transmission lines. Melting is performed at a voltage of 110 kV, employing a special transformer at the Western Ukraine substation. Icing condition indicators were installed at radio communications stations at five points along the route (at the highest elevations) to warn of line icing.

Conductor transposition and cable mutual transposition arrangements (for reducing induced voltages on the wires) were laid out for the entire line segment between the Western Ukraine and Albertirsa substations (one conductor transposition cycle and 12 cable transpositions).

The insulator strings for suspending the conductors were designed as multiple-chain: suspension -- paired, of 2 x 44PS-12A, 2 x 39PS-16B, and 2 x 37PS-22B insulators, depending on the effective loads; Vee suspension (on PRS supports) -- with paired branches of the same number of insulators; strain insulators -- four-chain, of 4 x 37PS-22B insulators. Shielding fittings were employed only on Vee-suspension and strain insulator strings.

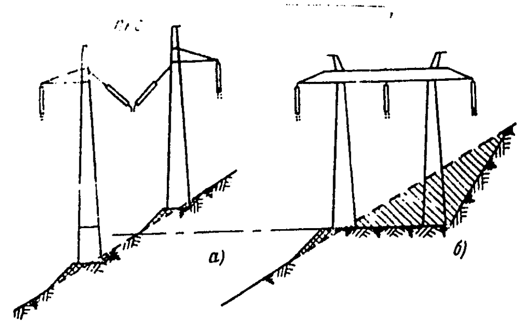

Figure 4. PRS separate-tower support (a), and free-standing PP support (b) on mountain terrain.

Paired conductor separators, which had performed well on 330-500 kV overhead power transmission lines on mountain terrain, were employed on the mountain-terrain section. Hinge-type separators were placed five units to a group, with spacing between groups of not more than 60 meters, and not more than 50 meters in the heavy icing area.

Figures on number of supports and consumption of basic materials per kilometer of mountain-terrain overhead power transmission line are listed below:

Number of supports:	
intermediate	2.13
angle	0.76
Consumption of materials:	
metal structures	64.5 tons
reinforced concrete for foundations	19.9 m^3
AS400/93 conductor	22.9 tons
AS95/141 cable	2.8 tons

Organization of Construction

Special work methods were developed for mountain terrain on power line routes, temporary vehicle access roads were built, arrangements for transporting supplies to the right-of-way, arrangements for erecting intermediate supports with separate towers (PRS), erecting conductor and mounting loops, etc.

We should state that delivery of supplies to a power line right-of-way on mountain terrain is one of the most difficult problems. During workup of the preliminary project plan, the route was surveyed, with determination of possible approach routes to tower sites, road sections requiring widening and grading, and additional forest clearing required.

The road network in the Carpathians, in the area of the power transmission line right-of-way, was built in a period when vehicles were small. Therefore railway bridge vertical clearances are too low to pass most of the vehicles of the mechanized columns. At these points it was necessary to unload supplies and equipment and pull them on sleds under every low-clearance bridge.

It was exceptionally rainy during construction of the power line. Heavy downpours on mountain slopes washed out temporary access roads, as a result of which it was necessary to regrade and even find new access road routes. This naturally increased the volume of earth moving severalfold.

On slopes and declivities with a grade of more than 7°, it is necessary to level sites where equipment operates. The volume of leveling and grading work increases for towers with a base of 5 meters or more at such sites. This is due to the fact that excavation (or placing of foundations) is impossible from one excavator (or crane) standing location.

We should note that for normal securement of foundations in the ground it is necessary that not less than half of the foundation height be in undisturbed soil, with the remainder in fill. Therefore on steep slopes and declivities the tower base should be lowered sufficiently to ensure reliable foundation securement. All these matters were settled in a comprehensive manner when drawing up the power transmission line plans and the foundation construction plans. Tower sites were surveyed (scale 1:200 or 1:100) for marking out the excavation area and erection sites on mountain terrain, vehicle passage locations and layout sites for supports with a tower base of 5 meters or more. This made it possible to determine temporary site leveling marks for the period of tower erection and permanent site leveling marks to be maintained following foundation placement and backfilling. Placement of towers was checked on the basis of the surveyor's marks (at sites where the foundation top marks were lowered), and when necessary correction of support types or individual towers would be made.

Employment of the PRS free-standing intermediate support with separate towers on mountain terrain made it possible substantially to reduce volume of site grading (Figure 4).

After building access roads and performing site grading and leveling, foundations were placed and backfilled with conventional methods. Reinforcing, digging of water runoff diversion ditches and site restoration were performed during backfilling.

Guyed intermediate supports were assembled from prefabricated sections delivered from a preliminary assembly site, while large free-standing towers were assembled directly at the erection site (due to limited space, the latter were assembled in sections, not in panels as was done on flatland terrain).

All supports erected on mountain terrain were subdivided into groups on the basis of steepness of slope. Erection sequences were drawn up for all types of supports, and rigging requirements were figured for each group. As a result, sets of rigging were set up for the different tower erection variants.

Conductors were installed by rolling them across a mounting pulley in a downhill direction.

Spacers were mounted on the conductors from special carriages traveling along the conductors.

Installation of horizontal conductor loops on angle supports merits special mention. In conformity with the plan of operation, the arch was assembled on the ground, conductor sections of the required length were placed in its terminals, after which the arch was raised and secured in position, and the loop conductors were welded at two points (near the strain clamps). With this erection setup it is not necessary for erection workers to go out onto the arch, and welding of the loops is performed from the strain insulator strings.

Regular supervisory inspections were conducted during power transmission line construction: inspectors would check the quality of structures and equipment received from the manufacturers, conditions of storage, quality and conformity to design of principal types of performed construction-erection work; they would determine typical mistakes in performance of these jobs, would check correctness of loading and off-loading structures, transport of structures, and would check to ensure that erection methods were in conformity with the approved project plan.

In order correctly to appraise the quality of work performed and its conformity with the plan, the Ukrainian Department of Energoset'proyekt drew up "Standards and Allowances in Construction of Overhead Power Transmission Lines," which reflect specific allowable departures for all types of structures employed on an overhead power transmission line. This work was based on current standards, Construction Standards, and Regulations, working drawings for 750 kV overhead power transmission lines, rules for setting up electrical installations, and Department Technical Specifications-750. Copies of the above-mentioned "Standards and Allowances" were given to each erection section of the mechanized columns and representatives of the client's technical inspectorate for practical application.

In spite of complex geologic and climatic conditions, the power transmission line was built in record time, with excellent quality of construction. This became possible thanks to constant close contact between specialists of the design, construction and operating organizations.

Conclusions

1. Employment of reinforced conductors and cables on power transmission lines across mountain terrain makes it possible to reduce the number of supports on the line, to select the most efficient support locations, and thus to reduce metal structures and reinforced concrete requirements, earth moving and excavation work volume, and to reduce the cost of delivering materials to field camps.

2. With employment of supports with separate towers on power transmission lines across mountain terrain, there is a substantial reduction in leveling, grading and excavation work, and a savings in metal is achieved.

3. On mountain-terrain power transmission lines it is advisable to employ special foundations (bored pile, bedrock-anchored, poured concrete, etc), which will reduce volume of earth moving and reinforcing work and will promote environmental protection.

4. Field adjustment of the siting of supports in the process of laying out power transmission lines across mountain terrain makes it possible to adopt the most efficient technical solutions.

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CONSTRUCTION OF 750 KV SUBSTATIONS DETAILED

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 7, Jul 80 pp 53-55

[Article by Engineers Ya. A. Nakonechnyy and V. N. Gudziy: "Construction of 750 kV Substations"]

[Text] The Trans-Ukraine 750 kV main power transmission line, which crosses the Central Ukraine from east to west, consists of two parts: Donbass-Dnieper-Vinnitsa, and Vinnitsa-Western Ukraine substation. On the Vinnitsa (USSR)-Albertirsa (Hungarian People's Republic) section of the 750 kV line, used for international electric power transmission, two main 750 kV substations have been built, the Vinnitsa, and the Western Ukraine substation. The latter is a main substation providing parallel operation of the South power grids (Donbassenergo, Dneproenergo, Vinnitsaenergo, L'vovenergo) with the power grids of the CEMA member nations.

The Ukrainian Department of the Energoset'proyekt Institute, which produced the substation plans, determined the positioning of the substation structures on the basis of convenience of operation, economy and maximum reduction of the length of service and cable lines.

750/330 kV autotransformer groups, groups of reactors, induction regulators and ice melting transformers are positioned along a spur track for moving transformers between 750 and 330 kV open-air switchboards. The 750 kV ORU [Outdoor Distribution System] (see photo [photo omitted]) employs a one and a half layout with three-row placement of disconnecting switches between two bus systems (the ORU contains a total of 15 bays with bay spacing of 46 meters). Galvanized metal portals of three types are employed for the 750 kV ORU -- bay, bus, and cross connection; conductor mounting height is 33.5, 23.5, and 29 meters respectively. The 330 kV ORU also employs a three-row disconnect switch arrangement; a total of 12 bays were built, utilizing single-span metal galvanized portals. All equipment in the 750 and 330 kV ORU was mounted on reinforced concrete piles.

We should state that performance of construction work on the site designated for construction of the Western Ukraine substation was complicated by many factors. For example, the site was in a flooded state practically year-round. During the time construction was in progress, the water table was at the ground surface. The water presented a general acid, leaching and carbonic acid aggressive environment. This dictated the necessity of employing reinforced concrete structures, as well as structures of pozzolana-cement concrete. In connection with the fact that the site topography was complex (there were slopes and depressions), a considerable amount of earth moving was required (for example, gravel-sand fill was brought to a height of 4 meters).

The substation OPU [Substation Control Center] building is three stories, with a prefabricated reinforced concrete frame. Prefabricated keramzite-concrete panels faced with "iriska" tile are employed in the exterior walls. The building contains double strip windows with metal sash.

The first floor contains the communications center, storage batteries, 6 kV distribution system, 16/04 kV combined transformer substation, electric-fired boiler unit, as well as offices and employee service rooms; the second floor contains primarily cable equipment, and the third story -- control console, relay panel, 330 and 750 kV automatic control equipment.

The control computer complex (UVK) building was erected in the process of construction of the second unit. It is architecturally the same as the OPU building. In connection with operational requirements, however, the interior layout is somewhat modified.

In addition, the substation site also contains a high-pressure compressor house and an auxiliary repair-maintenance building with transformer and oil equipment inspection tower.

We list below specifications for the 750 kV substation:

Fenced site area	56 hectares
Enclosure fence parameter	3180 meters
Estimated cost	39.8 million rubles
Of that, construction-installation work	15.1 million rubles
Quantity of installed equipment:	
autotransformer group (3x330), 1000 MV A	3
reactor group (3x100), 330 MV A	5
750 kV ORU	15 bays
330 kV ORU	12 bays
Work volumes:	
earth moving	457,000 m^3
erection of prefabricated reinforced concrete	31,400 m^3
erection of metal structures	7,116 tons

Mechanized column No 80 of the Yugzapelektroset'stroy Trust was general contractor for construction of this substation, performing all general construction work. The principal subcontractor organizations included subdivisions of the Elektroyuzhmontazh and Energostroymontazhsvyaz' trusts, which did the electrical installation and communications equipment installation work.

In certain cases subcontractor organizations of other ministries and agencies were secured to perform specialized jobs (drilling of artesian wells, laying of spur tracks, etc).

The following subdivisions were organized for performing general construction work:

for driving piles, assembly and erection of metal structures, installation of cable channels, electrical grounding, construction of roads and water drainage channels -- a group of brigades subordinate to the job superintendent;

for assembly of substation control center building, OZREN [expansion unknown] building, compressor house, indoor distribution systems, erection of building frames, installation of metal window sashes, welding and assembly of metal structures -- a second group of brigades under the job superintendent;

for finish work in the buildings (plastering, painting walls, installing windows and doors, glazing, painting and finishing floors) -- a brigade led by a foreman;

for plumbing installation work (laying exterior water lines, sewer lines, emergency oil drain lines, installing interior plumbing and ventilation equipment) -- a specialized brigade headed by a foreman;

for off-loading and transporting structures (receiving freight, loading and off-loading operations at the freight yard, hauling structures to the construction site storage facility) -- a special subdivision headed by a foreman; inspection to verify completeness of supply deliveries was assigned to one of the engineer-technician personnel.

With this specialization, labor productivity increased significantly, and there was an improvement in the quality of work performed.

Mess halls were built at the construction site, as well as housing consisting of PDU buildings, accommodating 300 workers. Some workers (approximately 70 persons) commuted to the jobsite by motor vehicle.

A number of changes were made in the plans in the process of construction, which made it possible to improve the exterior appearance of the buildings, as well as the entire site. For the most part the improved appearance was achieved with utilization of new types of construction and finishing materials. Aluminum replaced steel in all window pane framing.

In the rooms and corridors of the first through third floors all pipes (water, fire extinguishing and heating) were moved into the appropriate spaces, and heating system radiators in the control panel room were covered with decorative grills. Stairwell metal stringers were plastered over Rabitz wire netting. Polished wood (oak) components and plastic handrails were employed in stair railings. Stair treads were finished with colored marble chips and pigments. Floors in the first-story main room are inlaid, and on the second and third floors -- floors consist of marble tiles and slabs manufactured by Transcarpathian building materials plants. Doors in the entrance hall, main rooms on the second and third floors, and door frames are faced with single-ply light-colored wood veneer. Partitions and doors in the control panel room are paneled in light-tone veneer.

The design of the suspended ceilings was changed in the control panel room, third-floor main room, and corridors. Suspended ceilings in the control panel room and third-floor main room are of Akmigran ceiling tiles, and in the corridors -- of 810 x 810 cm gypsum panels.

Walls, ceilings and structural elements were painted in conformity with special instructions. Paint colors were chosen taking into consideration directional orientation of the rooms, as well as their functional designation.

A number of jobs involving installation of decorative elements of embossing, colored ceramic and wood, as well as visual propaganda elements, were performed by the L'vov Department of the USSR Art Foundation.

On-site roads and areas adjacent to buildings, which the plan specified to be of prefabricated reinforced concrete slabs, became partially damaged during construction and were coated with a 50-70 mm layer of bituminous concrete.

The standard inner fence with reinforced concrete posts was replaced with a postless fence with shoulders, painted with aluminum powder. The exterior fence of standard components on the ORU site was modified. The 100-150 mm wide gaps between the metal frames and reinforced concrete members were eliminated. The frames were mounted flush against the reinforced concrete posts and the partially-buried base slabs.

As already noted, the construction site had a high water table. Therefore it was necessary to construct an extensive water drainage system. In order to speed construction and improve the aesthetic appearance of the substation's 330-750 kV ORU, the builders employed UBK-5 reinforced concrete slabs in place of poured concrete. The substation site was extensively planted in greenery. Spreading trees and shrubs were planted in rows and clumps, which made it possible to separate the employee rest and recreation areas from the substation buildings and outdoor oil storage.

We should state that the preliminary design and working drawings for construction of the Western Ukraine 750 kV substation were prepared in a highly professional manner by the Ukrainian Department of the Energoset'-proyekt Institute. The designers adopted a number of new technical solutions which made it possible to improve construction efficiency, decrease consumption of rolled metal, reduce labor outlays, and ensure excellent quality of construction of buildings and other structures.

In the opinion of the builders, however, the following is essential in order to achieve further improvement in project design and engineering and to ensure high quality of construction work:

in designing the main buildings of substations, it is desirable to specify aluminum windows, suspended ceilings of Akmigran tiles in place of aluminum sheet, floors of different-colored tile materials, as well as improved-quality door fill and finish work on walls and ceilings;

water pipes and fire extinguishing sprinkler pipes should not run exposed in rooms and corridors;

substation access roads as well as principal on-site roads should be designed taking into consideration performance of construction in two stages: first stage -- laying reinforced concrete slabs at initiation of construction; second stage -- asphalt-concrete paving of roads and construction of curbs after completion of main construction work;

terraces for 330-750 kV ORU should be provided on marshy and flooded sites, where a considerable volume of landfill must be performed;

exterior water drainage ditches should not be simply bare dirt. Ditch slopes should be reinforced with concrete slabs as is done by the land reclamation people; prefabricated reinforced concrete gutter structures should be designed for on-site water drainage ditches, in order fully to eliminate poured-in-place ditch bottoms which, incidentally, have a service life of only 2 or 3 years.

The construction people have complaints to lodge against the plants of Glavenergostroyprom, which unfortunately have been devoting inadequate attention to the quality of their prefabricated reinforced concrete structures -- equipment mounting supports, cable trays, and cable tray cover slabs.

In planning work for the first construction-in-progress year it is advisable to provide, when needed, for construction of a permanent rail spur to the substation and to allocate appropriate structures and materials for this purpose. This will make it easier to deliver supplies to the jobsite and will make it possible sharply to reduce expenditures on loading-unloading and transport activities.

Execution of the above-enumerated measures will make it possible substantially to shorten the construction time frame and improve quality of construction of 750 kV substations.

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FIRST 750 KV TRANSMISSION LINES FOR SOUTH POWER GRID

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[Article by Engineers V. M. Babushkin, V. A. Neyman, V. A. Chevychelov, and Candidate of Technical Sciences L. F. Krivushkin: "Features of Selection of Layout and Parameters of First 750 kV Power Transmission Lines for South Integrated Power System"]

[Text] The first regular full-scale 750 kV power transmission lines in the USSR were designed and built in the Ukraine, in the South Integrated Power System (OES Yuga) -- one of this country's largest integrated power systems. In 1977 the Donbass-Western Ukraine 750 kV overhead power transmission line came fully on-line, which was of exceptional importance for further growth and development of power engineering in the Ukraine. It was now possible to provide reliable distribution of power generated by the Ladyzhin GRES, construction and movement on-stream of generator units at which were being accomplished at an accelerated pace, as well as power generated at the 3.6 million kilowatt Uglegorsk GRES, the largest in OES Yuga. Construction of this power transmission line made it possible more fully to implement the effect of integration of the power systems united in OES Yuga, and to create conditions for organizing parallel operation of the USSR Unified Power System with the integrated power system of the CEMA member nations.

The Ukrainian Department of the Energoset'proyekt Institute designed all components of the Donbass-Western Ukraine 750 kV power transmission line as well as those components of the international power transmission line situated on the territory of the USSR. The plans took into account data obtained on the Konakovo-Moscow experimental 750 kV line, and the concrete conditions of development of OES Yuga in the period 1975-1978. A number of Soviet scientific research institutes took part in working on individual items in selecting equipment parameters for the 750 kV power transmission line.

In order to increase the transmission capacity of the OES Yuga, the 750 kV transmission line route was selected in such a manner as to provide a tie-in not only with adjacent power systems in the west (Integrated Power

System of the CEMA member nations) and east (Center, Volga, and Northern Caucasus Integrated Power Systems), but also between the major power regions of OES Yuga -- Donbassenergo, Dneproenergo, L'vovenergo and the central part of OES Yuga (Vinnitsaenergo and Kievenergo). Construction of four 750/330 kV substations was specified for this purpose.

In order to ensure a reliable tie-in between the power regions and the 750 kV main power transmission line, the total capacity of the 750/330 kV autotransformers (AT) at the substations was specified at not less than 3 million kVA (initially plans called for installing two 750/330 kV AT rated at 1 million kVA each), with from 6 to 8 outgoing 330 kV lines.

In view of the overall system importance and special requirements imposed on the 750 kV substations, the plans did not specify construction of 150-110 kV distribution systems at these substations.

The layout and operating conditions of the 750 kV power transmission lines in OES Yuga are distinguished by a number of specific features. We shall examine the most important of these.

A variable load is characteristic of 750 kV power transmission line operating conditions. This is due to the influence of probability components of overcurrents, which is due to realization of the effect of integrating power systems on the scale of the USSR YeES [Unified Power System], as well as parallel operation with the OES of the CEMA member nations.

During designing of the first sections of the 750 kV power transmission line, development of power generating facilities of OES Yuga was oriented toward Donetsk coal, as a consequence of which 750 kV overhead power transmission line conductor sizes were selected proceeding from the assumption of constancy of power flow transmitted from the eastern regions of OES Yuga to the western regions. The adopted program of construction of nuclear power stations in the USSR YeES, and particularly in the OES Yuga, and subsequent elaborations of the growth and development plan of the latter indicated that plan-specified (balance) power flows would not significantly exceed 750 kV power transmission line variable load components, as a consequence of which 750 kV power transmission will to a substantial degree operate under intersystem connection conditions. On the basis of this, and taking into consideration the results of scientific elaborations completed by this time, it was decided to reduce the size of conductors on 750 kV lines from 2400 (4AS x 600) to 1600 mm^2 (4ASU x 400) per phase.

For an extended time during the initial stages of operation, 750 kV power transmission lines will operate in parallel with complexly closed 330 kV systems. This imposes substantial limitations on the operating conditions of 750 kV lines, full and economical utilization of their transmission capacity. In particular, natural distribution of flows of active power between a 750 kV power transmission line and parallel 330 kV systems proves to be unfavorable during this period as regards the condition of level of total active power losses. This dictates the advisability of installing at 750 kV substations special cross voltage regulation transformers (TPR), which makes it possible to bring current distribution close to the economically optimal with forced redistribution of active power flows between 750 kV power transmission and 330 kV systems. Employment of such transformers also makes it possible to a certain degree to expand capability of operating control of load on 330 kV system components and to eliminate when necessary overloading of individual components, which in turn will help increase the operational reliability of the system as a whole.

Parallel operation of 750 kV power transmission with the 330 kV system predetermines a close interlink between their operating conditions. For example, in spite of the fact that the 750 kV line load is relatively light during this period and does not exceed actual power, disconnection of individual 750 kV power transmission sections can lead to overloading of parallel 330 kV lines and, as a consequence of this, to division of the power systems into nonsynchronously operating parts. To prevent this, an automatic protection system is specified for power transmission lines.

Direct switching of generating capacities was not specified in designing the Donbass-Western Ukraine power transmission line, and therefore the 750/330 kV autotransformers at the substations were intended for operation in reversing mode in the direction of power transmission. Under these conditions the rated ratio of transformation for 750/330 kV AT was adopted equal to the ratio 750/330. Subsequently, in connection with increase in the number of units switched directly to a voltage of 750 kV at large power generating plants, it is advisable to establish the ratio of transformation of new 750/330 kV AT (particularly, higher-capacity transformers) at 750/347.

One of the features of 750 kV power transmission lines is the relatively short length of line sections. A length of 300-500 km can be considered most typical. This is due in the first place to the fairly high density of load in those regions of the European part of the USSR where the 750 kV network is to be developed, and secondly the fact that distances between adjacent power systems in the European part of the country do not exceed 500 km.

The Donbass-Western Ukraine power transmission line, with an overall length of 1,100 km, is divided by intermediate substations into three sections ranging from 320 to 420 km in length. Future plans call for construction of a shorter (200-300 km) 750 kV overhead power transmission line in OES Yuga.

The 750 kV equipment installed on the Konakovo-Moscow experimental 750 kV overhead power transmission line was radically changed in the process of designing 750 kV power transmission lines for OES Yuga, that is, equipment of practically new types was designed:

1000 MVA 750/330 kV autotransformers in a group;

a 1250 MVA 750/500 kV autotransformer in a group with high-capacity low-voltage winding and dynamic stability;

transformers for voltage cross control;

750 kV disconnect switches with increased speed and current parameters;

current transformers with a large number of secondary windings and a higher category of accuracy of measurement;

voltage transformers with a higher category of accuracy of measurements;

improved-design surge arrestors;

switches for reactor switching;

shunting reactors.

750 kV reactors are designed not only for limiting switching overvoltages, together with surge arrestors, but also for optimizing power transmission line operating conditions as regards reactive power. Future plans call for the possibility of installing 160 MVA synchronous compensators, connected to the tertiary windings of 750/330 kV autotransformers, with an increase in overcurrents in 750 kV overhead power transmission lines.

We should note that if the pace of development of nuclear power engineering in OES Yuga makes it possible fully to secure the system's power balance, with relatively shorter 750 kV power transmission line lengths, employment of conventional-type synchronous compensators at 750 kV substations will evidently prove uneconomical.

One problem which has not yet been resolved is that of development of a system of control of regulating devices installed on a power transmission line (load-supply relays, reactors, TPR) for ensuring optimal power transmission operating conditions.

The Donbass-Western Ukraine power transmission line is the first element of a future 750 kV network in OES Yuga. Further construction of 750 kV power lines will make it possible to establish the structure of an interconnecting grid and consequently to increase to a considerable degree the operating reliability of the 750 kV system -- the main system-forming component of OES Yuga. Priority is to be given to construction of overhead power transmission lines for transmitting power from a number of nuclear power stations under construction, such as the Chernobyl', Zaporozh'ye, and Southern Ukrainian.

In the period 1980-1985 annual volume of construction of 750 kV power transmission lines in OES Yuga will average approximately 400 km. Under these conditions one of the important tasks of planning and design is to bring the actually developing configuration of the 750 kV system in local regions as close as possible to the optimal 750 kV system configuration for OES Yuga as a whole.

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